CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Zero Motorcycles' Strategic Expansion of Volume Manufacturing Capacity for Electric Motorcycle Production in California

Prepared for: California Energy Commission

Prepared by: Zero Motorcycles, Inc.

ZERO MOTORCYCLES

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-11-604 for cost-sharing the development of manufacturing and/or assembly facilities in California that produce alternative fuel vehicles. In response to PON-11-604, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards June 20, 2012 and the agreement was executed as ARV-12-006 on November 8, 2012.

ABSTRACT

Zero Motorcycles, Inc., a California based company that designs, manufactures, and sells high performance electric motorcycles, identified an opportunity to increase its manufacturing volume and efficiency for building electric vehicles in California. Using both manufacturing and engineering process improvements and by placing new manufacturing lines into production, the company achieved a quadrupling of manufacturing capacity by the end of the project.

Under CEC Grant ARV-12-006, Zero Motorcycles, Inc. implemented the manufacturing and engineering changes required, purchased the equipment necessary to improve throughput and brought online significant new manufacturing capability, and then went into full scale volume manufacturing for its model year 2014 motorcycles.

Zero Motorcycles, Inc. successfully met all of the Strategic Expansion of Volume Manufacturing Capacity for Electric Motorcycle Production project objectives by enhancing its engineering and manufacturing processes and stepping up the scalability of its overall production. By the completion of the project, the company leveraged all of the engineering and manufacturing process improvements to go from an elapsed time of 66 minutes per station down to just 37 minutes per station. This represents an advancement of 78 percent. The overall manufacturing time went from 6:08 hours per motorcycle down to 4:10 hours, a 47 percent decrease. Zero Motorcycles, Inc. exceeded the goal of a 50 percent improvement in production workflow via process and design updates.

Zero Motorcycles, Inc. leveraged significant CEC and match funding for capital equipment to go from a fundamentally manual production system to a modern, flexible, and significantly more automated manufacturing line with higher degrees of process control. Not only will this gain the company the quadrupling of production capacity it sought, but it will come with higher quality product output as well.

This project has provided a platform to dramatically increase the California based manufacturing capacity of the next generation of efficient, practical electric vehicles and in turn reduced its cost of production. Zero Motorcycles, Inc.'s project has been a unique opportunity to manufacture significantly more electric motorcycles in California, exceeding consumer expectations, while replacing additional internal combustion vehicles in both California and worldwide fleets.

Keywords: California Energy Commission, Zero Motorcycles, Inc., electric vehicle, electric motorcycle, manufacturing, electric motor, SEVMC, electric fleets

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EXECUTIVE SUMMARY

Zero Motorcycles, Inc., a California based electric vehicle company that designs, manufactures, and sells high performance electric motorcycles, has successfully completed the Strategic Expansion of Volume Manufacturing Capacity for Electric Motorcycle Production Project –CEC Grant ARV-12-006.

Twenty-four months ago, Zero Motorcycles, Inc., identified an opportunity to increase its manufacturing volume and efficiency for building electric vehicles in California. Using both manufacturing and engineering process improvements and by placing a new primary manufacturing line and pilot line into production, the company succeeded at its goal of quadrupling manufacturing capacity by the end of the project. With the CEC's grant support of $1,815,123, matched by $2,041,762 from Zero Motorcycles, Inc., the company implemented the manufacturing and engineering changes required, purchased the equipment necessary to improve throughput and brought online significant new manufacturing capability, and then went into full scale volume manufacturing for its model year 2014 motorcycles.

Zero Motorcycles, Inc.'s Strategic Expansion of Volume Manufacturing Capacity for Electric Motorcycle Production Project advanced the state of manufacturing techniques used to produce electric motorcycles today. Significant portions of the United States' and especially California's manufacturing base have moved elsewhere in the past 20 years. The company believes that it is possible to counter this trend: the company is currently successfully designing and building high performance electric motorcycles here in California. The company previously investigated and implemented contract manufacturing in Asia, but later chose to bring full manufacturing back to the United States. California manufacturing allows us to achieve higher quality and better process control through onshoring rather than outsourcing.

With the CEC's support under this grant, we expanded and scaled up our new factory in Scotts Valley, CA. By leveraging design and process efficiency improvements, along with investment in capital equipment and tooling, the company is better able to manufacture competitive products with scalable volume production and reduced costs in California. The key issue for successful California manufacturing is achieving enough cost reduction to make the advantages of onshoring sustainable as a business model. The CEC funding was ideally suited for this kind of project and our company fully matched and exceeded the investment, leveraging 21st century California cleantech manufacturing to reach this goal.

The overall goal of this project was to create a program that strategically expanded Zero Motorcycles, Inc.'s full vehicle electric motorcycle production capacity and scaled the production facility with systematic redesign and manufacturing line improvements. These improvements included an expansion of our manufacturing footprint through the addition of a new production line, as well as an increasing our production efficiency via a strategic redesign of most of our manufacturing and engineering processes. The Strategic Expansion of Volume Manufacturing Capacity for Electric Motorcycle Production Project had a number of principal goals as well as a number of supporting goals which were completed.

The company successfully met all of the Strategic Expansion of Volume Manufacturing Capacity for Electric Motorcycle Production project objectives. At each step of the way the company improved its engineering and manufacturing processes improving the scalability of its

overall production. By the completion of the project, Zero Motorcycles, Inc. leveraged all of the engineering and manufacturing process improvements to go from 66 minutes per station down to just 37 minutes per station. This represents an advancement of 78 percent. The overall manufacturing time went from 6:08 hours per motorcycle down to 4:10 hours, an improvement of 47 percent. The company clearly met and exceeded the goal of a 50 percent improvement in production workflow (as measured by motorcycles produced per labor hour) via process and design updates.

The company leveraged almost $2 million in CEC and match funding for capital equipment to go from a fundamentally manual production system to a modern, flexible, and significantly more automated manufacturing line with much higher degrees of process control. Not only will this gain Zero Motorcycles, Inc. the quadrupling of production capacity it sought, but it will come with higher quality product output as well.

This project has provided a platform to dramatically increase the California based manufacturing capacity of the next generation of efficient, practical electric vehicles and in turn reduced its cost of production. Zero Motorcycle, Inc.'s project has been a unique opportunity to expand Greentech manufacturing in the State of California and on the Central Coast, keeping the competitive advantage of our skilled labor force, and helping to create twenty additional jobs during both the implementation and volume manufacturing stages of the project.

While the quadrupling of volume manufacturing capacity for electric motorcycle production has been a significant achievement for the CEC's Assembly Bill 118 program, it was also a strategic priority for Zero Motorcycles, Inc. as a company in advancing the overall state of the electric vehicle market. The two parties' incentives aligned extremely well for a successful completion of the Strategic Expansion of Volume Manufacturing Capacity for Electric Motorcycle Production Project here in California.

CHAPTER 1: Project Goals and Objectives

Project Goals and Objectives

- Zero Motorcycles, Inc. (Zero or Zero Motorcycles) redesigned many of the individual electric motorcycle product components to increase manufacturing efficiency of these components using Design for Manufacturing techniques
- Zero reviewed manufacturing processes for scaling the production of the new motorcycle designs and implemented identified improvements
- Substantial improvements in production workflow and efficiency via process optimization and automation were gained
- Identified and purchased capital equipment to improve efficiency, reduce cost, and directly expand capacity
- Tested preproduction pilot manufacturing to identify bottlenecks and make initial improvements
- Implemented fully scalable and efficient flexible volume production for the 2014 Model Year (14MY) product line

Supporting Goals

- Improved and optimized facility utilization at Zero Motorcycles Scotts Valley, CA factory for the Strategic Expansion of Volume Manufacturing Capacity for Electric Motorcycle Production (SEVMC) Project
- Improved and then expanded direct production energy utilization by implementing grid tie primary electric vehicle charging/discharging capability
- Improved production and final vehicle quality using additional capital equipment purchases

Quantitative and Measurable Objectives

- Designed engineering and manufacturing processes for the scalable production of electric motorcycles in Scotts Valley, CA and documented the results
- Achieved a 50 percent improvement in production workflow (as measured by motorcycles produced per labor hour) via process and design updates
- Leveraged capital expenditures to invest in an additional production and pilot line
- Used the above factors to accomplish a quadrupling (4x) of overall electric motorcycle manufacturing capacity

CHAPTER 2: Project Budget, Match and Spending Summary

The original spending targets for the project were CEC funding of $1,815,123 matched by $1,829,598 from Zero. Due to small delays in the project based on supplier issues and synchronizing more effectively with Zero's final product development and manufacturing schedule, the project was extended by approximately three months. There was no impact to the CEC funding, however Zero made additional investments in labor, personnel, and material costs bringing the final matching funds total to $2,041,762. The CEC project cost came in just under budget at $1,815,046.

Table 1 and 2 show a complete summary of SEVMC Project Spending. Zero strongly believes that the additional investment of $212,164 was worthwhile and beneficial for the overall project and has yielded a highly successful outcome with the key goals being met or exceeded.

Project Spending Summary

Table 1: Project Spending Summary, Including CEC Share

Commission Reimbursable Expenses Billed to Date				
Task		**Billed to Date**	**Budget Amt.**	**% Funds Expended to Date**
1.0	Administration of project	$33,930.82	$33,483.09	101%
2.0	Review & redesign engineering and manufacturing processes to increase production capacity	$487,728.08	$488,095.58	100%
3.0	Design & install pilot manufacturing line for 14MY and build prototypes to validate new processes, identify bottlenecks & improve processes	$584,691.88	$585,443.60	100%
4.0	Build automated full production line for 14MY production and performance test the line for increased efficiency & capacity	$708,695.56	$708,100.45	100%
Total		**$ 1,815,046.34**	$1,815,122.72	100.0%

Source: Zero Motorcycles

Table 2: Project Spending Summary, Including Match Share

Match Expenditure to Date				
Task		**Matched to Date**	**Match Funding Budget**	**% of Match Funds Expended**
1.0	Administration of project	$93,285.92	$121,264.00	76.9%
2.0	Review & redesign engineering and manufacturing process to increase production capacity	$528,312.71	$600,994.00	87.9%
3.0	Design & install pilot manufacturing line for 14MY and build prototypes to validate new processes, identity bottlenecks & improve processes	$488,328.51	$579,782.00	84.2%
4.0	Build automated full production line for 14MY production and performance test the line for increased efficiency & capacity	$931,834.69	$527,558.00	176.6%
Total		**$2,041,761.83**	$1,829,598.00	111.6%

Source: Zero Motorcycles

Project Match Summary

The following Matching Funds were obtained and deployed on the project: $424,394 from the 380 El Pueblo Road Facility Landlord, and $1,617,368 from Zero. This totals $2,041,762 of Match Funds, yielding a final Match contribution of 52.9 percent and a final CEC contribution of 47.1 percent.

CHAPTER 3: Introduction

Once an idea conceived inside a Santa Cruz, California garage, Zero Motorcycles has rapidly grown into an internationally recognized, world leading electric motorcycle company. Since 2006, when the first prototypes were produced, over three thousand Zero Motorcycles have been shipped to customers.

Zero Motorcycles partnered with The Invus Group, LLC in 2008 and as Zero's lead investor, is based in New York and provides Zero with the support necessary to transform the motorcycle industry – strategic insight, management advice, and capital to help the company grow. Invus Group, LLC has a strong record of long-term investing in companies and working with their management teams as they build successful businesses.

The company has expanded from that small garage to a 50,000 square foot facility in Scotts Valley, CA, with sales across the globe. The company has a solid, multiyear growth plan including annually audited financials. Currently, more than 110 employees support Zero's operations, including manufacturing, research and development to engineering, business administration, sales, and marketing.

Zero Motorcycles has a rich history of innovation in the burgeoning electric vehicle industry. By combining the best aspects of a traditional motorcycle with today's most advanced technology, Zero produces high performance electric motorcycles that are lightweight, efficient,

and fast off the line without the associated pollution (noise, fumes, and spills) or maintenance of traditional internal combustion motorcycles. The Zero team has proven experience turning innovative ideas into real products and delivering them to the market. Evidenced by our full lineup of clean, efficient, electric vehicles, Zero Motorcycles' impact is real and on the road.

For the past five years Zero Motorcycles has been executing a continuous cycle of improving its engineering and manufacturing processes. By late 2009, in an effort to rapidly bring the motorcycle rolling chassis to parity with other major motorcycle companies, Zero Motorcycles chose to begin offshore manufacturing to benefit from the perceived lower labor costs. The original 12,000 square foot Zero Scotts Valley factory was essentially setup as a pilot production line to develop the processes needed for outsourcing. Coincident with this, Zero began to ramp an Asian contract manufacturer for volume production. However, Zero soon realized that the impact and overhead to a small entrepreneurial company of outsourcing manufacturing over 6,000 miles away from its engineering team was not going to allow the company to achieve its quality metrics, engineering flexibility, or overall production goals.

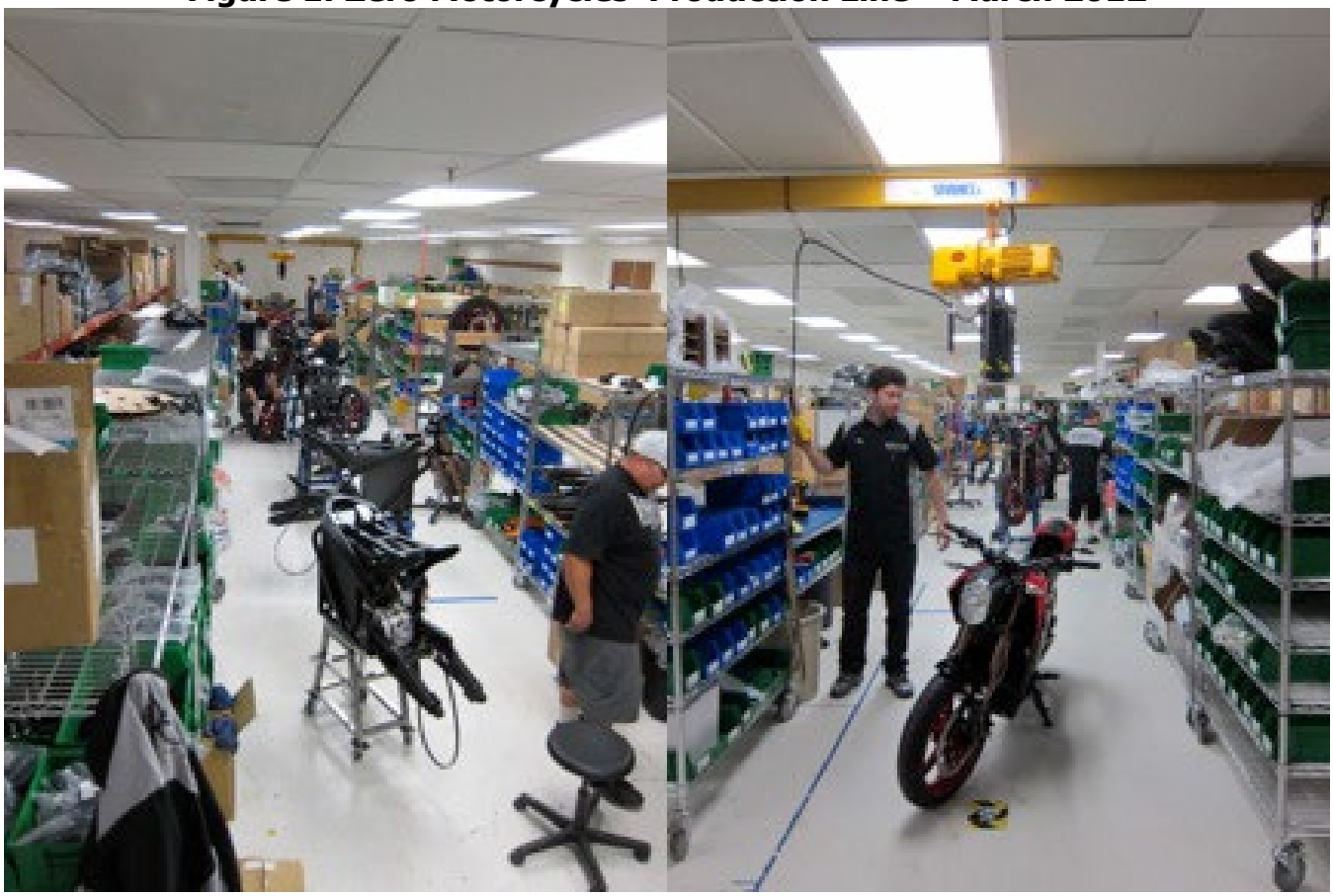
In mid-2010, the executive team at Zero made the key decision to bring all manufacturing back to California, in essence, onshoring. After careful financial analysis, Zero put forth a compelling business case to its investors and a great sales and marketing story bb Crafted in California, USA bb that supported this initiative. Zero reasoned that employing a highly skilled workforce in California would ensure a high-quality product without significantly eroding margins. This strategic shift allowed Zero to begin maintaining a year-round pilot

production line and also created a much closer working relationship between the manufacturing and engineering teams. The now established collaboration fosters creativity and innovation that Zero leveraged during the SEVMC Project. Volume production enabled by this project will also allow Zero to further strengthen its role in the California economy.

A lease to occupy a larger existing space in a Scotts Valley, CA facility was entered into at the end of 2010, expanding the factory to a 38,000 square foot footprint, with the availability of approximately 20,000 square foot of additional space in the same facility. The repurposed factory was fully operational by March 2011. The factory infrastructure, equipment, and manufacturing model were scalable to manufacturing 1000 motorcycles annually. The 11MY bikes were all manufactured in this factory from March until August 2011, at which time we began durability and refinement prototype and validation builds for the 12MY motorcycles.

In late 2011, with an improved and maturing supply chain and in anticipation of much higher volumes, Zero Motorcycles once again reconfigured its full production line (Figure 1). This line started with the battery line and is sequence fed with parts and various subassemblies. This process forces visibility to parts shortages, quality issues, process inefficiencies, and manpower shortcomings, allowing the team to react quickly and resolve such deficiencies. All 12MY bikes were produced on this line.

Figure 1: Zero Motorcycles' Production Line – March 2012



Source: Zero Motorcycles

Based on dramatic product improvements in 12MY, including increased vehicle range, and a rapidly expanding dealer distribution network, product demand for Zero Motorcycles continued to grow.

Then two years ago, Zero Motorcycles identified an opportunity to increase its manufacturing scale, volume and efficiency for building electric vehicles in California by deploying significant capital investment and company personnel resources. Using a variety of engineering and manufacturing process improvements and placing a new primary manufacturing line and prototype line into production, Zero believed it could achieve a quadrupling of manufacturing capacity by the end of the SEVMC project.

This project has allowed Zero to undertake a strategic expansion of its electric motorcycle production capacity through systematic manufacturing line improvements. These improvements included an increase in our manufacturing floor footprint through addition of new production lines as well as improvements in our production efficiency via a redesign of most of our manufacturing and engineering processes.

The Zero Motorcycles' SEVMC manufacturing program leveraged the significant experience Zero has gained over the last five years as it has developed and deployed electric motorcycles into the marketplace. Zero implemented the engineering and manufacturing changes required, purchased the equipment necessary to improve throughput and bring online the new manufacturing capability, and went into full scale volume manufacturing for its 14MY electric motorcycle product line.

The SEVMC Project began with a redesign of the individual electric motorcycle product components and subassemblies to increase their manufacturing efficiency. Then Zero reviewed its manufacturing processes to scale the production of these new motorcycle designs. From this review, specific targets were identified to achieve substantial improvements in manufacturing production workflow and efficiency via process optimization and automation. Zero also identified and procured capital equipment to help implement efficiency processes and procedures, reducing cost and directly expanding capacity.

In Task 3 of the project implementation, Zero installed a new preproduction pilot manufacturing line and tested this line by building a set of durability and refinement motorcycles. It used the production of these prototype vehicles to identify bottlenecks and made process improvements to its manufacturing processes. Definition of a new set of process improvements were the final element of Task 3.

In the last phase of the project, Task 4, Zero installed its new flexible, full production line and tested this line with the production of a larger set of validation motorcycles. These were used to test production intent components and validate the manufacturing processes. At this stage Zero fully implemented the processes for scalable volume production on the 14MY product line. The 2014 production line is shown in Figure 2.

This project was designed to provide a platform to dramatically increase the California based manufacturing capacity and reduce the cost of the next generation of efficient, practical electric vehicles. Zero Motorcycle's SEVMC project created a unique opportunity to expand Greentech manufacturing in the State of California and on the Central Coast, keeping the

competitive advantage of our skilled labor force, and helping to create twenty additional jobs during both the implementation and volume manufacturing stages of the project.

Figure 2: Zero Motorcycles' 2014 Product Line

Source: Zero Motorcycles

CHAPTER 4: Project Task Summaries

The SEVMC project was broken up into four separate tasks, with Tasks 2-4 being the primary technical tasks. Task 1 included all of the grant administrative and reporting.

Task 1

The primary goals of Task 1 were to manage the project administration and reporting, including meetings with Commission staff, Monthly Reports, Critical Project Reviews, Contract Administration, and Final Reporting. Zero stayed up to date and on time with its reporting throughout the project. A summary of the Task 1 deliverables and their completion status is shown in Table 3.

Table 3: Goals and Status for Task 1

Scope of Work - Task 1	Final Status - Recommendations and Conclusions
Attend a "Kick-Off" meeting with Energy Commission Project Staff. The Recipient shall bring its appropriate staff members, the Commission Project Manager will provide an agenda to all potential meeting participants. Meeting will review requirements for all administrative tasks which are part of Task 1. (Task 1.1)	**Completed** - Kickoff Meeting held on 11/29/12.
Meet for two Critical Project Reviews (CPRs) to determine if the project should continue to receive Energy Commission funding to complete this Agreement and to identify any needed modifications to the tasks, products, schedule or budget. (Task 1.2)	**Completed** - CPR#1 Meeting held 5/7/13. CPR#2 Meeting held 10/10/13.
Meet with Energy Commission staff for Final Meeting to closeout Agreement presenting the findings, conclusions, and recommendations. The final meeting or conference call must be completed during the closeout of this Agreement. This meeting will be attended by Energy Commission Staff and Zero Staff. (Task 1.3)	*To be completed after delivery of Final Report.*
Provide Monthly Progress Reports to periodically verify that satisfactory and continued progress is made towards achieving the research objectives of this Agreement on time and within budget. (Task 1.4)	**Completed** - Provided 14 Monthly Progress Reports in a timely fashion to Energy Commssion staff.
Create a Final Report assessing the project's success in achieving its goals and objectives, advancing science and technology, and providing energy-related and other benefits to California. (Task 1.5)	**Completed** - Final Report sent to Energy Commission staff on 5/15/14.
Identify and obtain matching funds ensuring that the match funds planned for this Agreement are received and applied to this Agreement during the term of this Agreement. (Task 1.6)	**Completed** - All Matching Funds were obtained and deployed on the project. Matching funds included $424,394 from the 380 El Pueblo Road Facility Landlord, and $1,617,368 from Zero Motorcycles, Inc.
Identify and obtain required permits necessary for work completed under this Agreement in advance of the date they are needed to keep the Agreement schedule on track. (Task 1.7)	**Completed** - All permits were obtained and completed by 6/1/13.
Obtain and Execute Subcontracts required to carry out the tasks under this Agreement, and to procure them consistent with the terms and conditions of this Agreement. (Task 1.8)	**Completed** - All Subcontracts were executed and completed by 9/30/13.

Source: Zero Motorcycles

Task 2

The goal of Task 2 was to redesign Zero's electric motorcycle product line to make it inherently simpler to manufacture, as well as optimizing and automating key manufacturing processes to gain substantial improvements in production workflow in order to scale the production of these new designs. One of the major steps of this task was to complete the 14MY design and create this Engineering & Manufacturing Redesign Report, which was delivered to the CEC on May 7, 2013. The goals and status of Task 2 is shown in Table 4.

Table 4: Goals and Status for Task 2

Scope of Work - Task 2	Final Status - Recommendations and Conclusions
Review all engineering processes and redesign motorcycles for MY14 to increase manufacturability and improve final vehicle quality	**Completed** - Process review for MY14 Durability and Refinement was completed and all components were sent to part suppliers for bid. Completed 3/23/13
Review and improve manufacturing process to increase production efficiency and optimize facility utilization resulting in increased capacity	**Completed** - Manufacturing process and supplier review has been completed. Increases to production efficiency and facility optimization continued dynamically throughout Tasks 3 and 4. Based on this Task 2 goal, improvements to date have resulted in increased capacity of 17%. Pilot production of D&R motorcycles is underway.
Identify capital equipment, tooling, asset management systems & software needed to reduce costs, improve efficiency & directly expand capacity (including identifying equipment to offset manufacturing energy usage)	**Completed** - As part of Task 2, Zero has identified and purchased significant capital equipment, tooling, asset management systems & software needed to reduce costs, improve efficiency & directly expand capacity (including identifying equipment to offset manufacturing energy usage). One of the major successes has been the purchase of the Aerovironment MT-30 Battery Cycler which has been identified as being able to cut significant time out of the battery manufacturing process per motorcycle, while increasing overall safety.
Purchase pre-production tooling, equipment, software, etc. needed for engineering & manufacturing process improvement activities	**Completed** - Pre-production tooling, equipment, software, and other supplies needed for engineering & manufacturing process improvement activities have been purchased or are in the procurement cycle.
Prepare "Engineering and Manufacturing Process Redesign Report" summarizing the engineering & manufacturing processes changes need for MY14 and listing the expected efficiency improvements and capacity gains	**Completed** - Engineering and Manufacturing Process Redesign Report provided to Energy Commission staff on 5/7/13.

Source: Zero Motorcycles

Task 3

The goal of Task 3 was to prepare the manufacturing facilities for all tooling and pilot line build out, install the tooling for the pilot line, and use the installed pilot line to produce two prototype motorcycles in order to validate the new engineering design and processes as well as identify manufacturing bottlenecks and make improvements where needed. One of the major deliverables of this task was to complete two 14MY durability and refinement Motorcycles (Zero FX & Zero SR) and create this Pilot Manufacturing Line Description, Photographs of Prototype Motorcycles, and Process Validation Report, which was delivered to the CEC on October 10, 2013. The goals and status for Task 3 is shown in Table 5.

Table 5: Goals and Status for Task 3

Scope of Work - Task 3	Final Status - Recommendations and Conclusions
Design pilot manufacturing line based on reviewed engineering and manufacturing processes defined in Task 2.	**Completed** - Production engineering staff has completed the pilot line along with the D&R motorcycles.
Make necessary building facility modification to support the installation of the pilot line.	**Completed** - Significant modifications were made to the facility as part of the facility move.
Purchase & install capital equipment & tooling identified in Task 2 that are needed for prototype building on pilot line. Manage tooling installation & software for pilot line.	**Completed** - Equipment purchases, software acquisition and tooling are underway.
Build 2 prototype motorcycles (D&R bike 1 and D&R bike 2) on pilot manufacturing line to validate engineering design and processes	**Completed** - D&R motorcycle build is complete
Identify manufacturing bottlenecks while building prototype bikes using pilot line. Determine process improvements needed to address manufacturing bottlenecks for full production line.	**Completed/Ongoing** - Production engineering has reviewed D&R data to determine possible bottlenecks. Additional work will continue during the Validation Phase/Task 4
Prepare and submit a "Pilot Manufacturing Line Description, Photographs of Prototype Motorcyles, and Process Validation Report" describing new pilot manufacturing line including descriptions of tooling and equipment installations, facility layout, photos of pilot line & prototype motorcycles, etc.	**Completed** - Submitted to the Energy Commission on October 10th, 2013

Source: Zero Motorcycles

Task 4

The goal of Task 4 was to prepare the building for all tooling and full manufacturing line build out, install the tooling & equipment for the automated manufacturing line, and use the installed automated full manufacturing line to produce at least 15 validation motorcycles in order to test performance of the assembly line. Twenty-seven validation motorcycles were actually produced during Task 4, further optimizing the manufacturing process. The goals and status for Task 4 is shown in Table 6.

Table 6: Goals and Status for Task 4

Scope of Work - Task 4	Final Status - Recommendations and Conclusions
Make necessary building facility modifications to support the installation of the manufacturing equipment & full production line	**Completed** - Significant modifications were made to the facility as part of the facility move and completed during Tasks 3 and 4.
Order and procure the necessary equipment and materials for establishment of the manufacturing line	**Completed** - Equipment purchases, software acquisition and tooling are completed.
Manage the tooling installation, work flow logistics, software installation, and asset management systems. Install engineering systems management, asset management systems and software. Install tooling & equipment. Establish production line protocol.	**Completed** - Equipment purchases, software acquisition and tooling are complete for MY14.
Produce at least 15 validation motorcycles from the full production line while testing protocol compliance as well as performance of new manufacturing line.	**Completed** - 27 Total validation motorcycles were built during the validation phase.
Prepare “Full Manufacturing Line Description Report”, including facility layout plan, descriptions of tooling and equipment installations, production line protocol, & the ability of the assembly line to produce motorcycles in compliance with the protocol.	**Completed** - The manufacturing line description is incorporated as part of this Final Report.
Prepare “Full Manufacturing Line Performance Report” analyzing performance (efficiency) and increased capacity of new production line.	**Completed** - The manufacturing line performance report is incorporated as part of this Final Report.

Source: Zero Motorcycles

CHAPTER 5: Project Task and Technical Details

The SEVMC project was broken up into four separate tasks, with Tasks 2-4 being the primary technical tasks. Task 1 included all of the grant administrative and reporting.

Task 1

The primary goals of Task 1 were to manage the project administration and reporting, including meetings with Commission staff, Monthly Reports, Critical Project Reviews, Contract Administration, and Final Reporting. Zero stayed up to date and on time with its reporting throughout the project. A total of 14 monthly reports were submitted along with two Critical Project Review presentations. Since Task 1 was an administrative and reporting task, the Task 1 Summary in Chapter 4 provides a complete assessment of the task completion.

Task 2

The goal of Task 2 was to redesign Zero's electric motorcycle product line to make it inherently simpler to manufacture, as well as optimizing and automating key manufacturing processes to gain substantial improvements in production workflow in order to scale the production of these new designs. One of the major steps of this task was to complete the 14MY design and create an Engineering & Manufacturing Redesign Report, which was delivered to the CEC on May 7nd, 2013.

Zero successfully completed all milestones of Task 2 including the submission of the Engineering & Manufacturing Redesign Report. Zero achieved significant design accomplishments and faced challenges during Task 2, creating the new 14MY Zero electric motorcycle designs and getting ready for the pilot production of the first 14MY Zero durability and refinement motorcycles.

Overcoming a major hurdle, Zero delayed the completion of Task 2 to allow moving to a new facility which enhanced our ability to execute on this grant program. Zero successfully recovered from the delay that was introduced by the move and was able to continue redesign efforts throughout Task 2.

In order to achieve the SEVMC project goals, Zero altered the overall timeline of the ARV-12-006 CEC grant project to match the revised production schedule of Zero's 14MY product line. The Commission Grant Manager approved this change in March 2013.

Throughout Task 2, Zero received or created preproduction components using the new designs, allowing the first prototypes of the 14MY motorcycle line to be built and the new prototype testing cycle to begin. As an ongoing process, Zero continued to refine the design and worked to determine the optimal suppliers and manufacturing processes.

As a result of the engineering and manufacturing redesign efforts completed during Task 2, Zero estimates that it has saved between $234 and $477 per motorcycle in component cost reductions. The highest level of savings occurred with our highest volume motorcycle, the Zero S. In addition, leveraging design for manufacturing principles and strategic capital investments based on Task 2 outcomes will save 80 to 153 person minutes per motorcycle in production, yielding an additional labor cost reduction of up to

$76.50 per motorcycle and more importantly, a capacity increase for our California factory of 17 percent from this initial engineering and manufacturing redesign.

Engineering Redesign Process

Zero Motorcycles' engineering team undertook the task as part of this project to evaluate and pursue cost savings within each part of the product line and across the entire company.

Throughout the process, "design for manufacturing" principles were used to optimize and focus the engineering effort. It was critical to Zero to make sure that while certain components were being optimized, that each of the platforms stayed reasonably stable in terms of suppliers and components. After several rounds of design reviews, Zero engineering was able to achieve significant reductions in both cost and manufacturing time by changing less than 15 percent of the motorcycles' components. A number of the changes and the impact are provided as examples below.

The most significant change, resulting in a cost savings of $200 and 60 person minutes of manufacturing time, came from the design and selection of a new onboard vehicle charger for the SDS platform. The unit, shown in Figure 3, replaces a more costly, labor intensive solution used in Zero's 12MY and 13MY models.

Figure 3: Zero Motorcycles 14MY Vehicle Charger

Source: Zero Motorcycles

Another representative change came from the use of a new higher performance braking system, shown in Figure 4. These rear brakes have improved handling and cost $10 less

per motorcycle. They also save 15 person minutes per motorcycle as they are provided to Zero as a pebbled braking system.

Figure 4: Zero Motorcycles 14MY Rear Brakes – Rear Caliper

Source: Zero Motorcycles

Zero also made changes to the frames and bodywork to reduce component counts, improve materials handling, and reduce manufacturing time. Examples include the chin fairing, shown in Figure 5, which was produced for 14MY durability and refinement using a rapid prototyping printer to save time and costs. This process allows a full check on the motorcycle before expensive tooling for full production is started.

Figure 5: Zero Motorcycles 14MY Chin Fairings

Source: Zero Motorcycles

As the engineering redesign process was underway, some of the engineers took on the specific task of looking at fasteners to rationalize uniform sizes and reduce the parts count as appropriate. The team was able to simplify and enhance the fender mounts as shown in Figure 6.

Figure 6: Zero Motorcycles 14MY Fender Mounts

Source: Zero Motorcycles

One additional area of progress toward improved manufacturability came from redesigning the wiring harnesses (Figure 7) and reviewing all of the wiring routing to reduce assembly labor (Figure 8). As we construct the 14MY durability and refinement motorcycles, we are paying particular attention to see if additional improvements can be achieved.

Figure 7: Zero Motorcycles 14MY Wiring Harness

Source: Zero Motorcycles

Figure 8: Zero Motorcycles 14MY XMX Frame Buildup

Source: Zero Motorcycles

Zero will discuss other process changes that result in cost and manufacturing improvements as the pilot production line comes online during Task 3 and further process improvements are documented.

Figure 9: Zero Motorcycles 14MY SDS Frame Buildup

Source: Zero Motorcycles

Facility Move

Zero was proceeding successfully in the execution of the grant when it was determined it was not possible to renegotiate our lease to gain the appropriate tenant improvements with the landlord at 170 Technology Circle in Scotts Valley, California. In order to update the facility to meet the goals of the project, the landlord wanted unacceptable changes in the lease terms. We immediately began searching for an alternate facility and successfully identified and secured a new facility located at 380 El Pueblo Road in Scotts Valley, CA, 1.2 miles from the previous facility. The new landlord has agreed to assist Zero in fully meeting the CEC project goals and requirements.

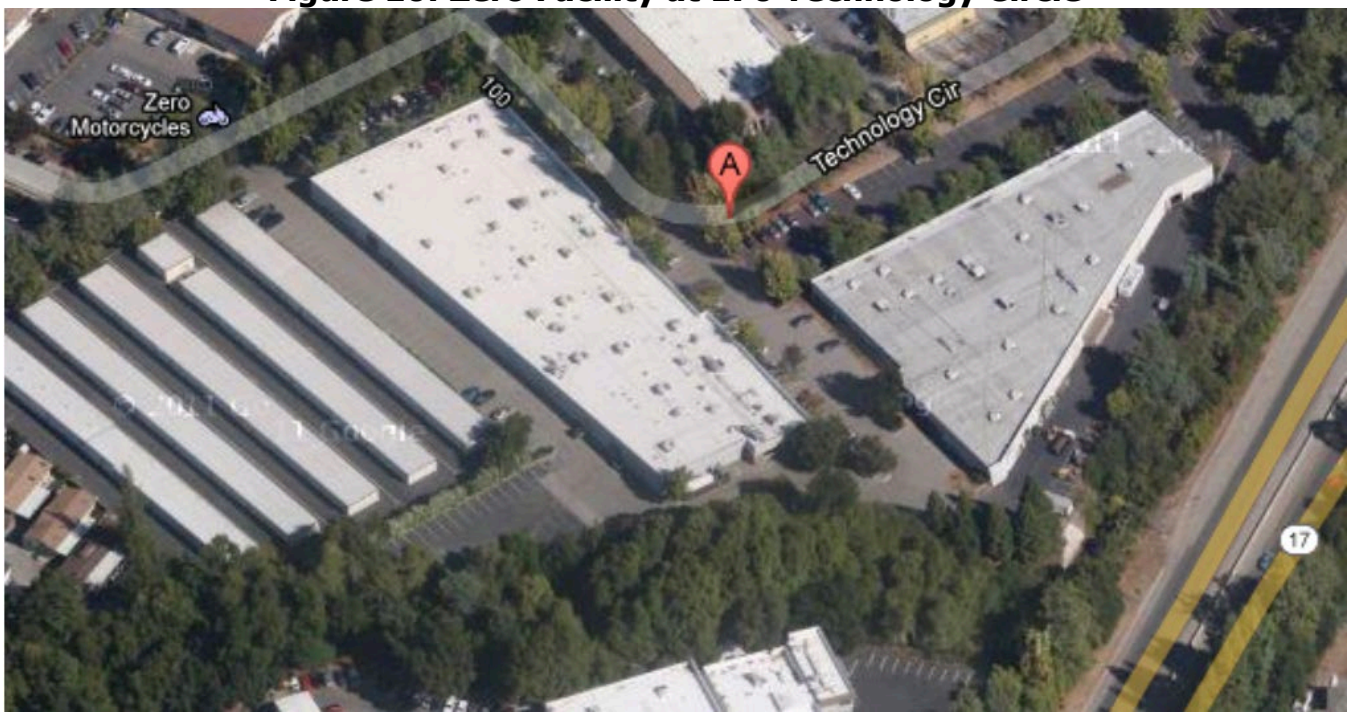
We completed lease negotiations in February 2013 and notified the CEC of our need to change the project location. We took occupancy of the facility and move in during March 2013. The City of Scotts Valley was extremely cooperative with the facility change and provided Zero Motorcycles with the California Environmental Quality Act (CEQA) Notice of

Exemption for 380 El Pueblo Road. The necessary CEQA documentation and a Revised Grant Attachment L were also provided to the CEC in February 2013.

The facility changes required for the project, including build out and move in, have allowed for a more optimized execution of the overall project in the 380 El Pueblo facility. As a result of the move, Zero requested delaying each of the remaining project milestones by 60 days. A revised schedule, ARV-12-006 Exhibit A, was approved by the Commission Grant Manager along with the other facility move documentation in February 2013.

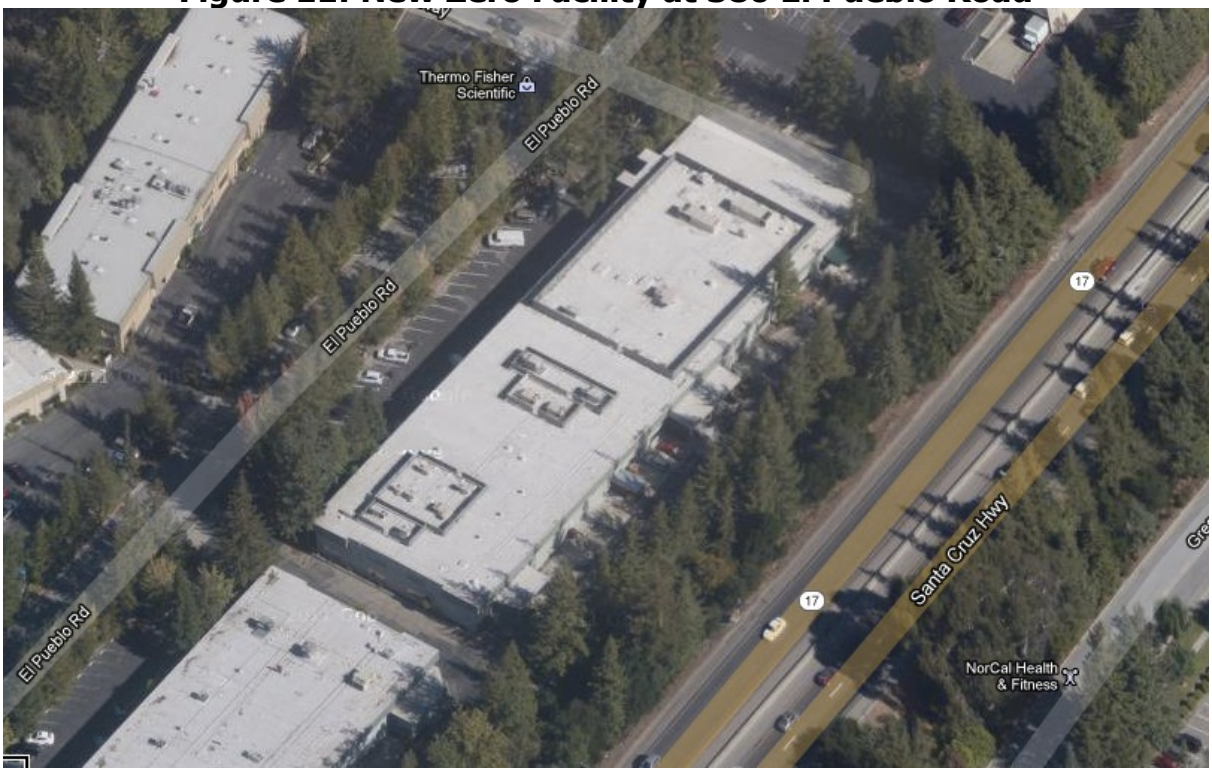
In addition to the increased available space, one of the other advantages of the new facility is the overall height and configuration of the building (Figure 12). Zero now has almost 50,000 square feet, up from 38,000 square feet at 170 Technology Circle. The clear height on the building is 24 feet vs only 14 feet previously, allowing for much more efficient space utilization, especially for warehousing. Finally, the building is rectangular, rather than trapezoidal and has loading and unloading docks to facilitate both incoming and outgoing shipping and receiving. Figures 10 & 11 show aerial views of both buildings.

Figure 10: Zero Facility at 170 Technology Circle



Source: Zero Motorcycles

Figure 11: New Zero Facility at 380 El Pueblo Road



Source: Zero Motorcycles

Figure 12: New Zero Warehouse with Height Advantage

Source: Zero Motorcycles

Task 3

The goal of Task 3 was to prepare the manufacturing facilities for all tooling and pilot line build out, install the tooling for the pilot line, and use the installed pilot line to produce two prototype motorcycles in order to validate the new engineering design and processes as well as identify manufacturing bottlenecks and make improvements where needed. One of the major deliverables of this task was to complete two 14MY durability and refinement Motorcycles (Zero FX & Zero SR) and create this Pilot Manufacturing Line Description, Photographs of Prototype Motorcycles, and Process Validation Report, which was delivered to the CEC on October 10th, 2013.

Zero successfully completed all milestones of Task 3 with the submission of the Pilot Manufacturing Line Description, Photographs of Prototype Motorcycles, and Process Validation Report. Zero summarized the engineering and manufacturing design accomplishments and challenges that Zero faced in Task 3, creating the new 14MY Zero electric motorcycles and achieving the pilot production of the first 14MY Zero durability and refinement motorcycles.

Zero delayed the completion of Task 3 when we encountered a major issue with our battery supplier, Farasis, requiring us to issue a voluntary recall on all 13MY FX and XU battery modules worldwide. Farasis has been an excellent supplier and worked closely with Zero to resolve the problem quickly. The 14MY battery modules which had been received for durability and refinement, validation and preproduction all exhibited the same defect, so Farasis worked to quickly replace these modules. Zero successfully recovered from the delay that was introduced by this issue and the resulting recall and was able to continue durability and refinement and pilot manufacturing efforts throughout Task 3. The first corrected 14MY battery modules for both durability and refinement and Validation arrived on September 5th. A project schedule revision for Task 3 completion of an additional 3 weeks and Task 4 completion of an additional 4 weeks were required to compensate for the overall issue.

As a result of the engineering and manufacturing pilot manufacturing efforts completed during Task 3, Zero estimated that it would achieve component cost reductions which will be fully determined during Task 4. In addition, leveraging design for manufacturing principles and strategic capital investments based on Task 3 outcomes will save up to 40 person minutes per motorcycle in production, yielding an additional labor cost reduction of up to $20 per motorcycle and more importantly, a capacity increase for our California factory of another 10 percent based on Task 3 engineering and manufacturing process design. Task 4 brought into focus the complete set of manufacturing time cycle analysis which further quantified the net savings on terms of both cost and time.

Engineering and Manufacturing Durability and Refinement Process and Process Validation, and Pilot Manufacturing Line Overview

Zero Motorcycles' engineering team undertook the task as part of this project to evaluate and pursue cost savings within each part of the product line and across the entire company.

Throughout the process, "design for manufacturing" principles were used to optimize and focus the engineering effort. The Durability and Refinement phase is the key time where the new model year motorcycle designs are proven and finalized.

One major part of this phase is approving component and vehicle durability testing, as well as approving component and vehicle functionality refinements. Designs are frozen and released including all bills of materials, drawings and firmware. These activities were all critical to the completion of Task 3. In addition, during durability and refinement motorcycle geometries, colors and surfaces are all finalized. The initial durability and refinement motorcycles are also used for regulatory pretesting, especially for battery and powertrain components. Zero's customer service operation uses durability and refinement to establish initial Service Part Plans and Service Publication Drafts. Zero's manufacturing team was able to develop the Task 3 pilot production line to produce the initial durability and refinement motorcycles as shown in Figures 13 and 14.

Figure 13: Zero Motorcycles 14MY Pilot Production Line

Source: Zero Motorcycles

Figure 14: Zero Motorcycles 14MY Pilot Production Line

Source: Zero Motorcycles

Task 3 aligned perfectly with the durability and refinement phase by project design (Figure 15). Components optimized during Task 2 were moved into the pilot production phase during Task 3.

Figure 15: Zero Motorcycles 14MY Durability and Refinement Frame Integration

Source: Zero Motorcycles

The pilot manufacturing line is a retooled version of Zero's 13MY production line with additional flexibility. This allows the line to be rapidly reconfigured to produce the full 14MY model line of Zero motorcycles. Zero leveraged the equipment purchases from Task 2 including the AeroVironment MT-30 Battery Cycler (Figure 16) which was able to cut significant time out of the battery manufacturing process per motorcycle, while increasing overall safety.

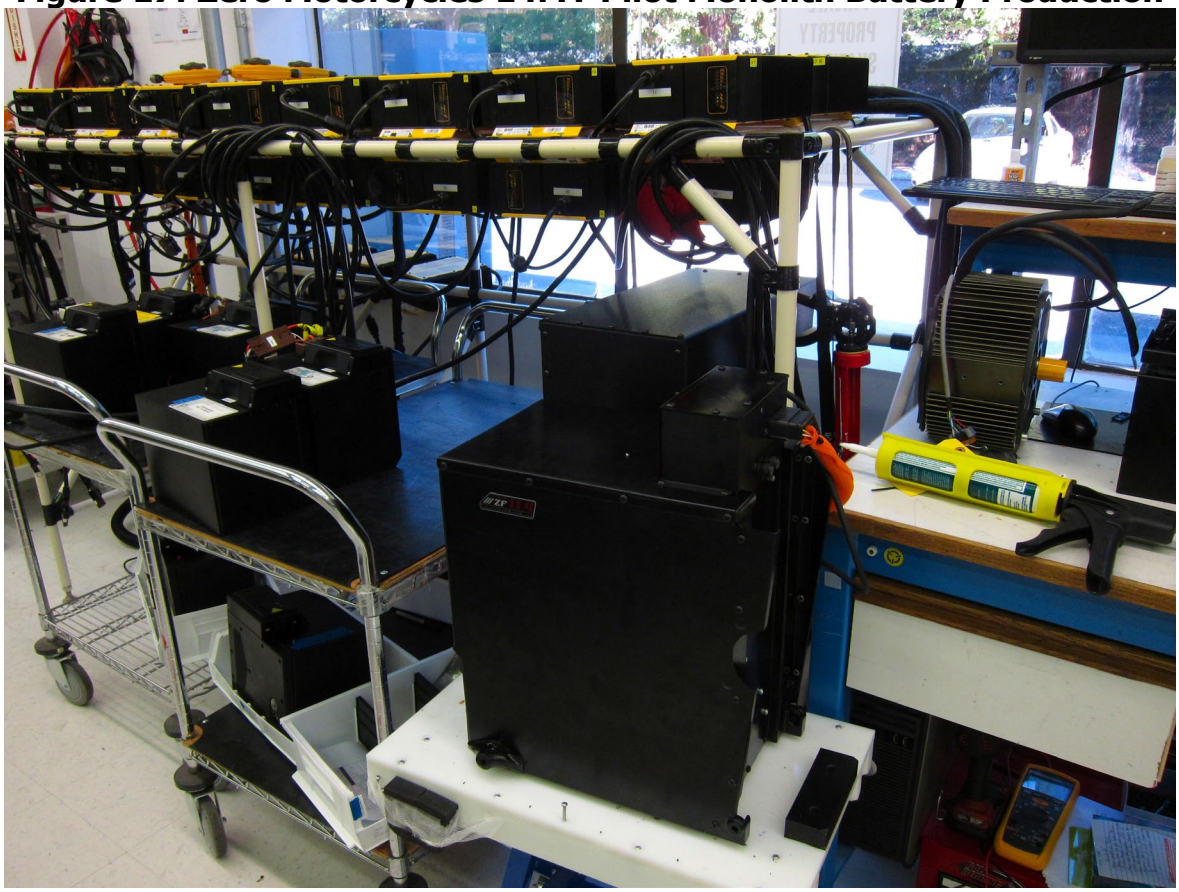
Figure 16: Zero Motorcycles MT-30 Grid Tied Charging of Durability and Refinement Batteries

Source: Zero Motorcycles

Production of battery modules and fully integrated packs has shown promising improvements during Task 3, however full cycle time testing with the new Farasis cellboxes will take place during Task 4 after we receive sufficient quantities of the new batteries.

Figures 17 and 18 show the pilot production of 14MY Monolith and Module Batteries. Again, the gains from engineering redesign and improved charging/discharging cycle times have further accelerated the production process. The Battery pack in Figure 17 represents the 11.4-kilowatt hours monolith pack consisting of four individual cellboxes. The Battery module in Figure 18 shows a single cellbox packaged into a module for use in Zero's XMX platforms.

Figure 17: Zero Motorcycles 14MY Pilot Monolith Battery Production



Source: Zero Motorcycles

Supplier Battery Issues

Zero was delayed the completion of Task 3 when we encountered a major issue with our battery supplier, Farasis, requiring us to issue a voluntary recall on all 13MY FX and XU battery modules worldwide. A limited number of the modular battery cellboxes may contain a manufacturing defect in the internal sealing compound that could in some instances allow water to penetrate the cellbbox and contact the cells. Should water reach the cells, the cells may corrode and eventually release their electrolyte. The electrolyte could then form a conductive path between cells, which may lead to a rapid temperature increase and off gassing of the battery.

Farasis was an excellent supplier and worked closely with Zero to resolve the problem quickly. The 14MY battery modules which had been received for durability and refinement, validation and preproduction all exhibited the same defect, so Farasis worked to quickly replace these modules. Zero successfully recovered from the delay that was introduced by this issue and the resulting recall and was able to continue durability and refinement and pilot manufacturing efforts throughout Task 3. The first corrected 14MY battery modules for both durability and refinement and Validation arrived on September 5th. A project schedule revision for Task 3 completion of an additional 3 weeks and Task 4 completion of an additional 4 weeks were required to compensate for the overall issue.

Figure 18: Zero Motorcycles 14MY Battery Module

Source: Zero Motorcycles

Task 4

The goal of Task 4 was to prepare the building for all tooling and full manufacturing line build out, install the tooling & equipment for the automated manufacturing line, and use the installed automated full manufacturing line to produce at least 15 validation motorcycles in order to test performance of the assembly line. Twenty-seven validation motorcycles were actually produced during Task 4, further optimizing the manufacturing process.

Zero successfully completed all milestones of Task 4 with the submission of our Final Project Report. Zero has summarized the manufacturing production accomplishments and challenges that Zero faced in Task 4 below, creating the new 14MY Zero electric motorcycles and achieving the production of the first 14MY Zero validation motorcycles.

Zero was initially quite concerned about the delay introduced by our battery supplier during Task 3. The 14MY battery modules which had been received for validation and pre-

production all exhibited the same defect, so Farasis worked to quickly replace these modules. Zero successfully recovered from the delay that was introduced by this issue and the resulting recall and was able to continue validation and preproduction manufacturing efforts for Task 4. The first corrected 14MY battery modules for both durability and refinement and Validation arrived on September 5th. A project schedule revision for Task 4 completion required an additional 4 weeks to compensate for the overall issue.

As a result of the engineering and manufacturing pilot manufacturing efforts completed during Tasks 2 and 3, Zero achieved final component cost reductions during Task 4. In addition, leveraging design for manufacturing principles and strategic capital investments based on Task 3 outcomes will save up to 40 person minutes per motorcycle in production, yielding an additional labor cost reduction of up to $20 per motorcycle and more importantly, a capacity increase for our California factory of another 10 percent based on Task 3 engineering and manufacturing process design. Task 4 brought into focus a complete set of manufacturing time cycle analysis which will further quantify the net savings on terms of both cost and time.

Upon completion of Task 4, Zero was able to fully achieve the initial productivity increases proposed for the project. Truly significant gains were obtained with the implementation of radio data terminals for scanning in and out of each workstation and new software which was implemented for the project which integrates time tracking and production line management to optimize production capacity. Zero was also able to efficiently leverage capital equipment funding from the project to purchase key equipment such as DC production tools and high-power battery cycling.

As a result of all the engineering and manufacturing efforts completed during Task 2, Task 3, and Task 4, Zero estimates that it will save between $268 and $512 per motorcycle in component cost reductions. In addition, leveraging design for manufacturing principles and strategic capital investments based on all outcomes has saved 105 to 196 person minutes per motorcycle in production, yielding an additional labor cost reduction of up to $98 per motorcycle and more importantly, an overall capacity increase for our California factory of 53 percent from this project's engineering and manufacturing redesign.

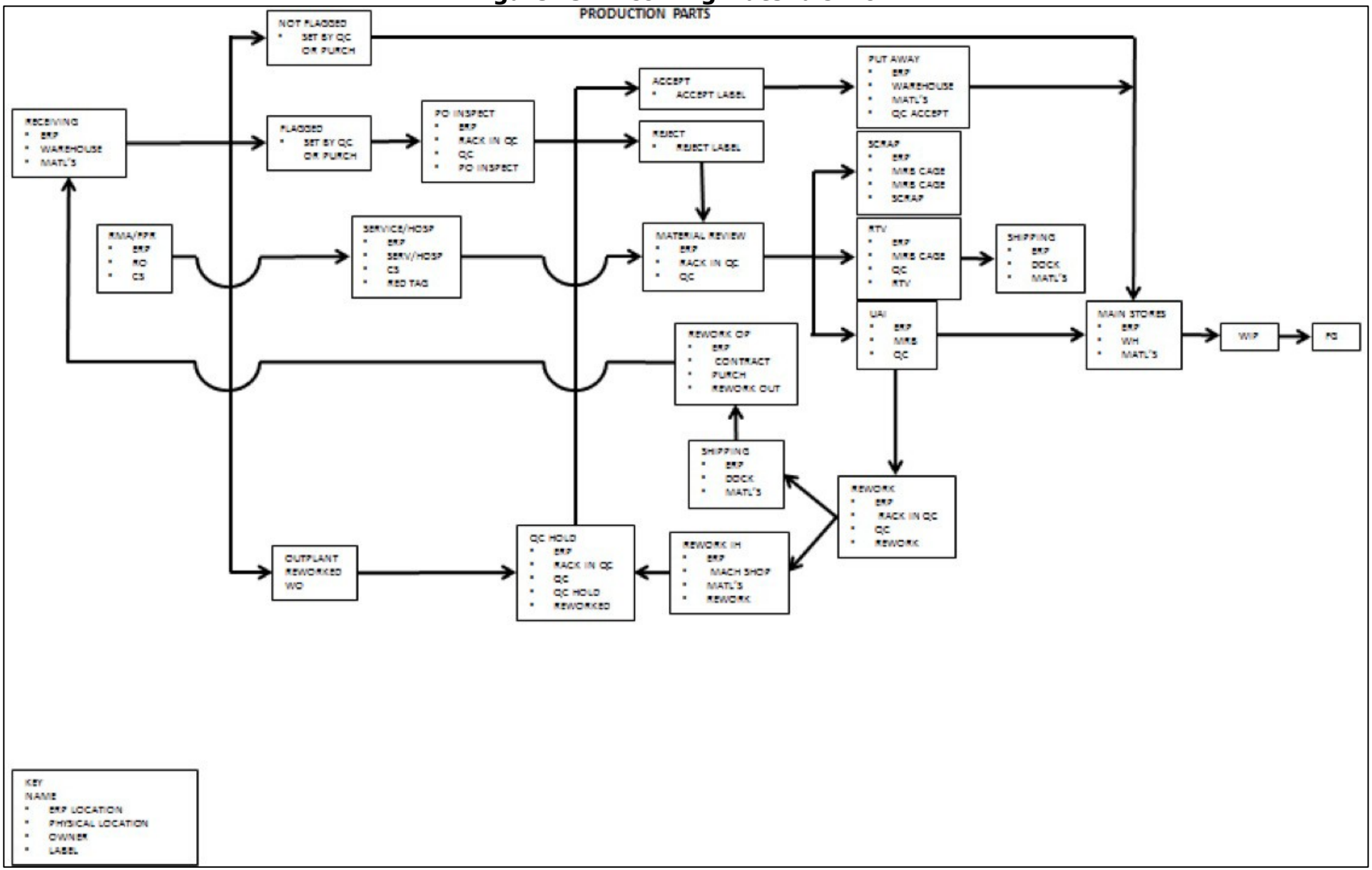
Full Manufacturing Line Description

At the beginning of the SEVMC project, Zero envisioned implementation of a fully automated production line to gain the greatest efficiency. As we completed the early tasks in this project it became clear that what was actually needed was a full process redesign and the implementation of a flexible production line which would be capable of building a wider variety of electric motorcycles, ranging from the Zero FX, to the Zero Police Fleet motorcycles which often need to be produced by the hundreds. The shift from automated manufacturing line to flexible manufacturing line was one of the key lessons learned from the project.

Zero initially made the necessary building facility modifications to the new 380 El Pueblo Road facility to support the installation of the manufacturing equipment & production lines. Then the manufacturing group ordered and procured the necessary equipment and materials for establishment of the expanded preproduction manufacturing line. This line would become the testbed and eventually the full manufacturing line.

The first area which was reengineered was the process for handling parts and incoming supplies for the production line. The diagram Figure 19 below shows the flowchart for incoming materials. Optimizing this part of the process was key to gaining increased production line efficiency. Figure 20 shows where the quality control checks are done during the production.

Figure 19: Incoming Materials Flow



Source: Zero Motorcycles

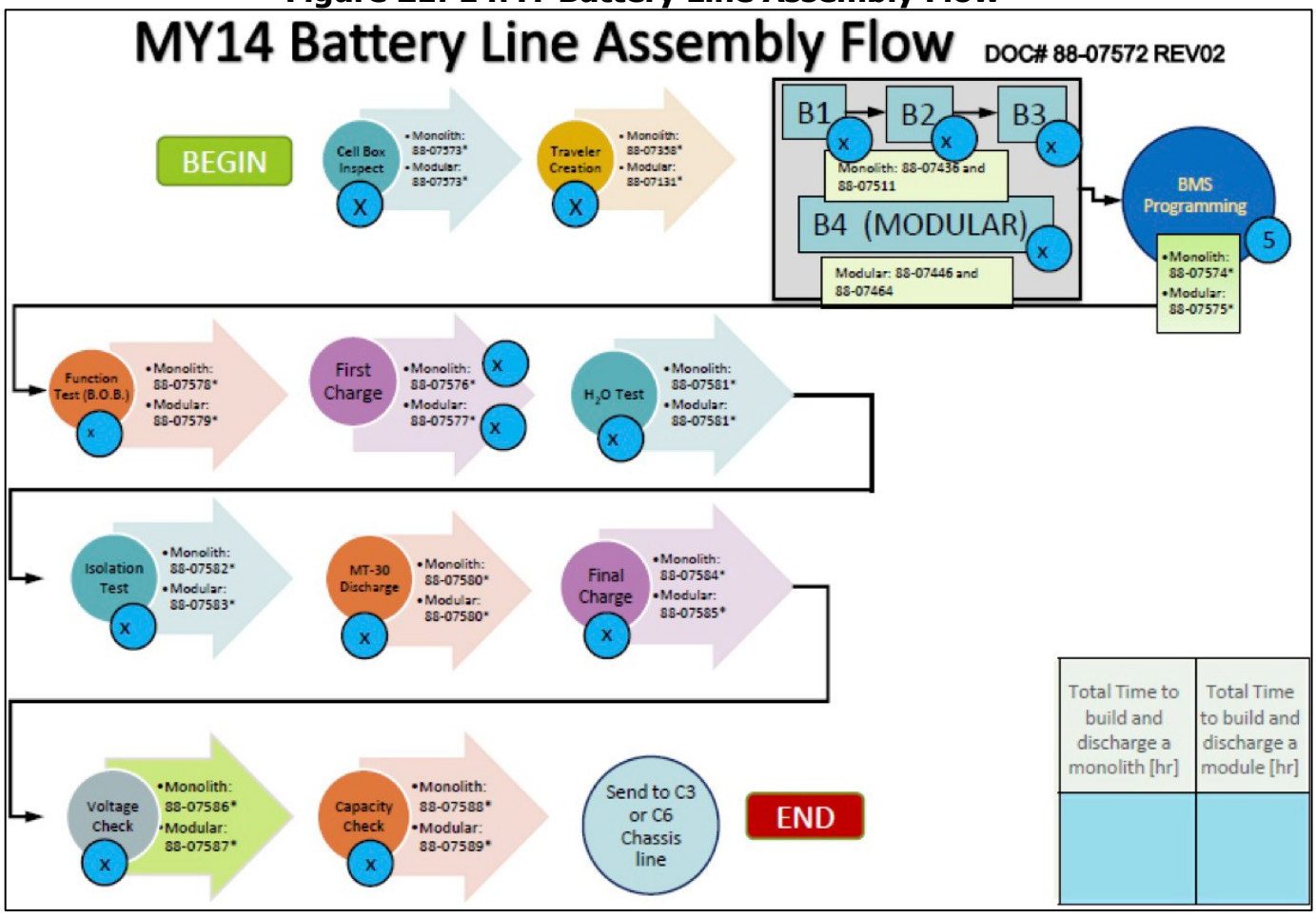
Figure 20: Quality Control on Incoming Parts

Source: Zero Motorcycles

The production engineering team worked closely with the engineering team during all tasks, but especially during Task 4. The diagram shown in Figure 21 shows the Battery

Assembly line flow and stations for our preproduction and final 14MY manufacturing. Figure 22 shows the battery line view.

Figure 21: 14MY Battery Line Assembly Flow



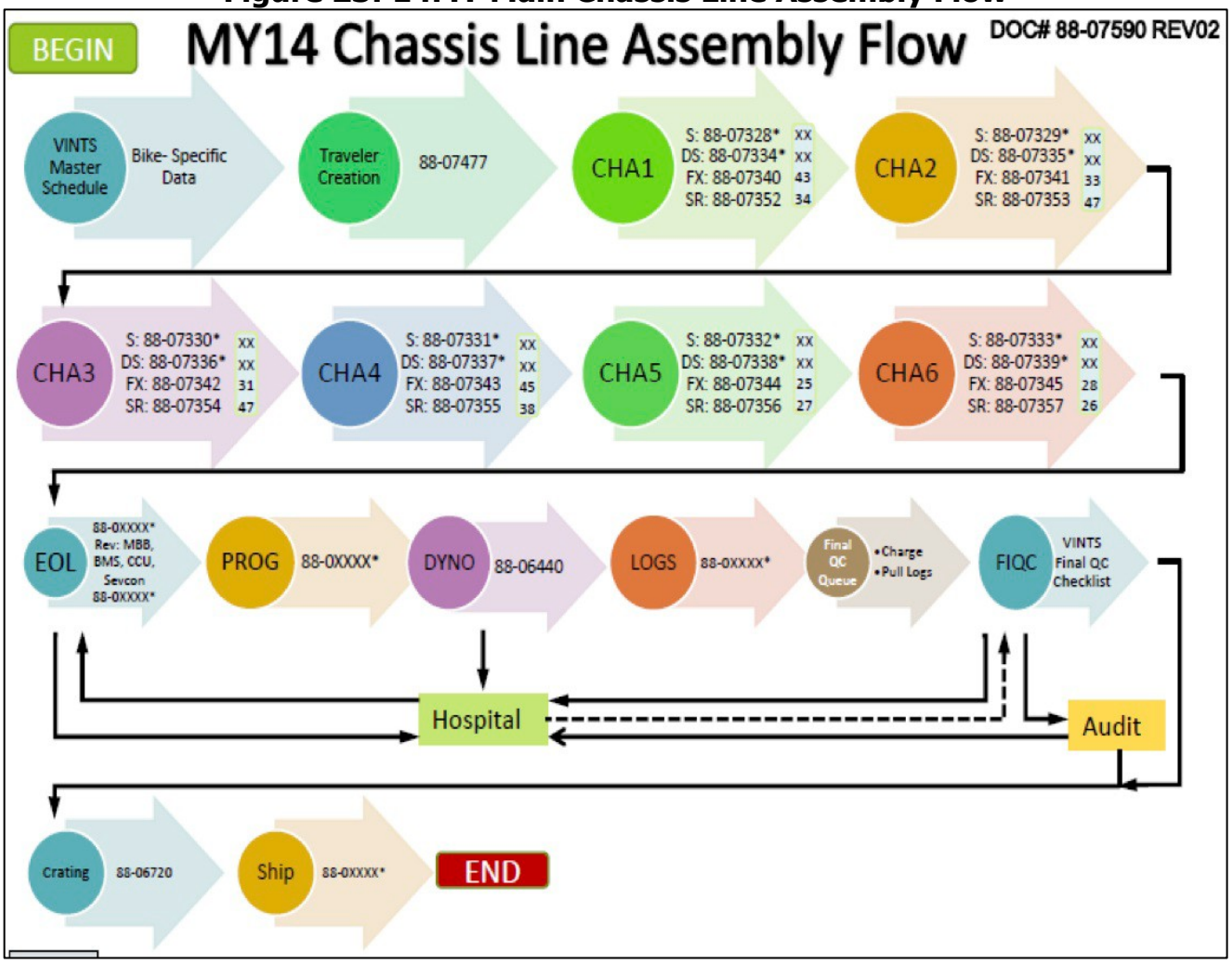
Source: Zero Motorcycles

Figure 22: 14MY Battery Line View

Source: Zero Motorcycles

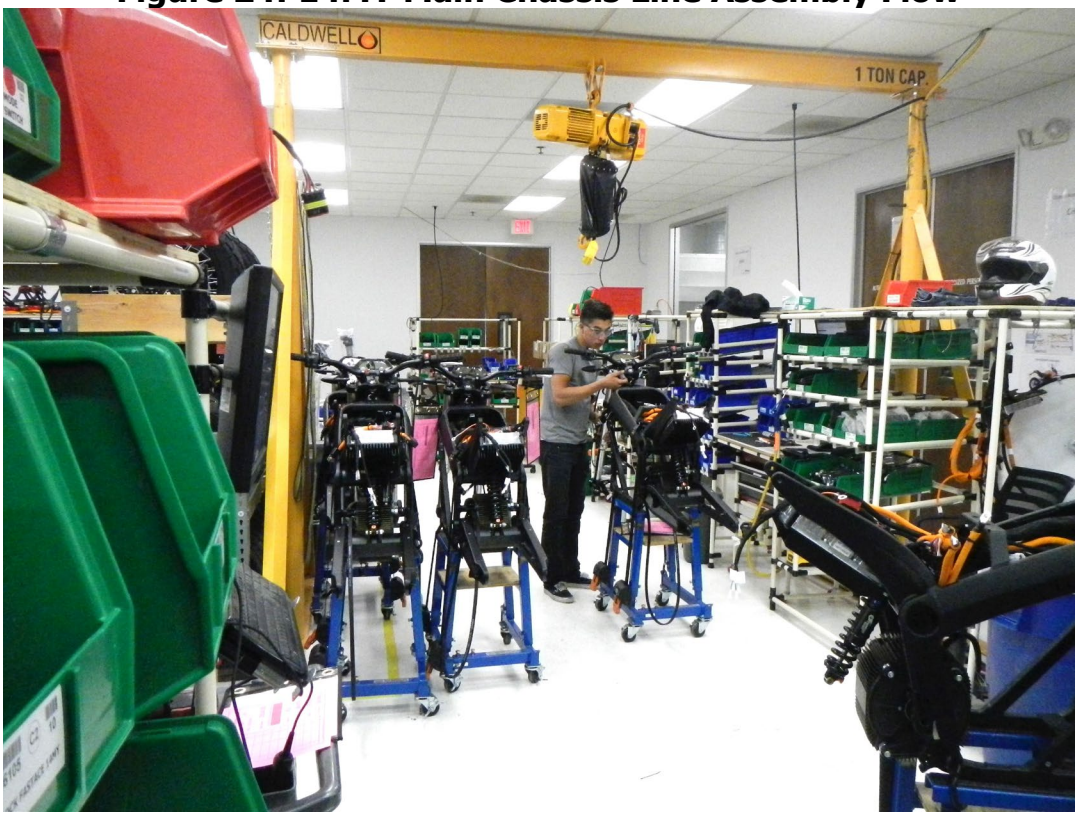
The diagram shown in Figure 23 shows the 14MY Chassis Line Assembly flow and stations for our preproduction and final 14MY manufacturing. This flow was optimized to manage multiple products and leverage the skilled Zero production workforce. Figures 24 and 25 show the main chassis line assembly flow. Figure 26 shows the final check along with the beginning of the shipping process.

Figure 23: 14MY Main Chassis Line Assembly Flow



Source: Zero Motorcycles

Figure 24: 14MY Main Chassis Line Assembly Flow

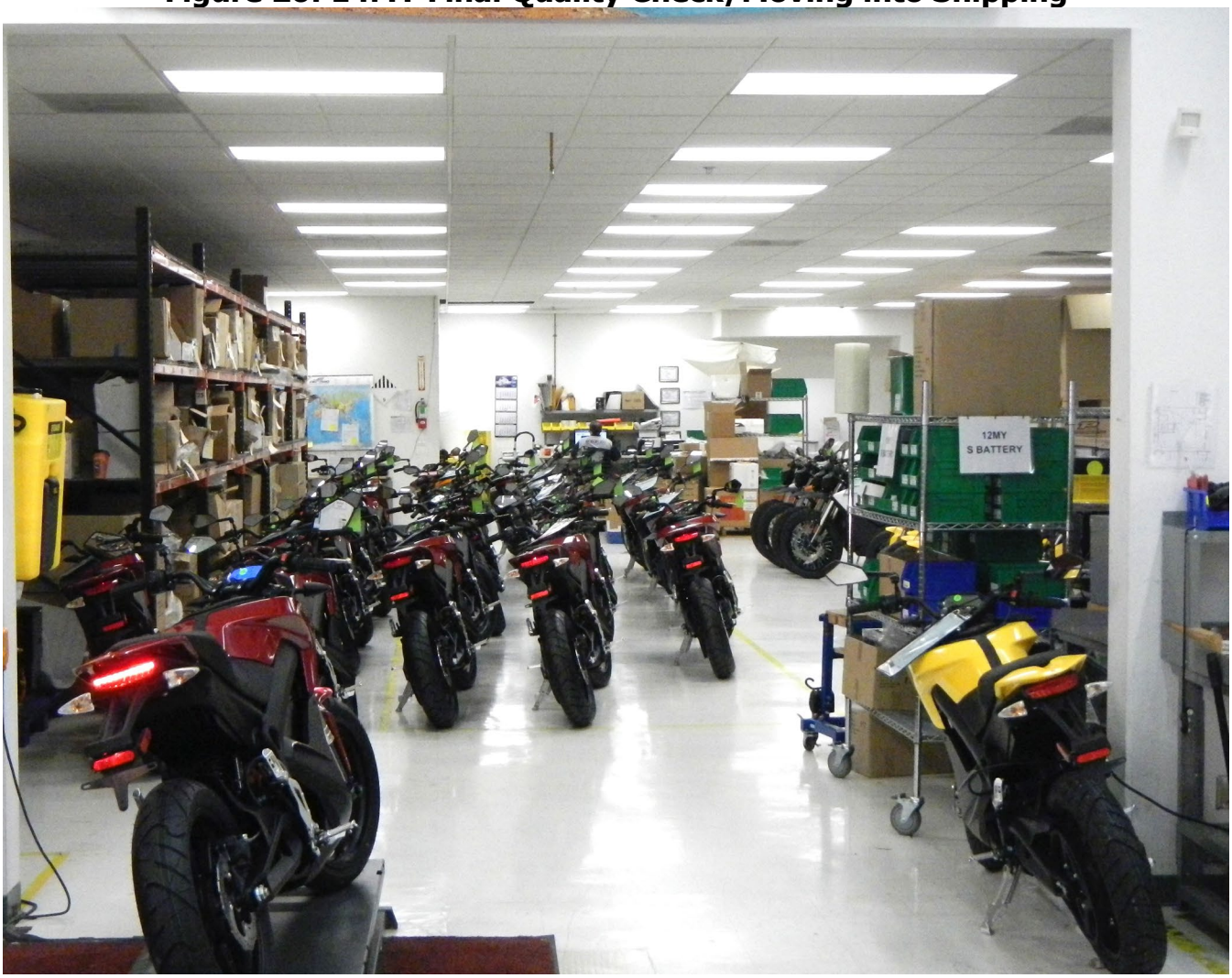


Source: Zero Motorcycles

Figure 25: 14MY Main Chassis Line Assembly Flow

Source: Zero Motorcycles

Figure 26: 14MY Final Quality Check/Moving into Shipping



Source: Zero Motorcycles

One of the specific capital investments made during the project was the implementation of DC manufacturing tools. These tools allow for preprogrammed repetitive actions and tasks such as torqueing bolts and completing assemblies. They allow for much better process control and monitoring, improved efficiency, and higher quality. The project budget included the investment of $216,000 in these high-performance tools, split equally between CEC funding and Zero Motorcycles' match funding. One of the other key benefits is that when a line operator needs to install 12 fasteners at a given station, the tools will provide instant feedback to prevent missed insertions. These tools are in use at Toyota, Nissan, Chrysler, Ford, GM, Honda and many other manufacturers and have been crucial to meeting project target goals. Zero is continuing to expand their use and is making additional investments in this area after achieving such a major success during the project.

One of the best investments Zero made as part of the project were the AeroVironment MT-30 Battery Cyclers (Figure 28). As discussed in Task 2, this equipment allows for rapid charging and discharging of battery modules simulating real world conditions (Figure 27). The first unit was purchased with $87,000 of CEC funds, however the manufacturing team found that the unit so enhanced throughput that a second one was purchased on Zero

matching funds. These units are also a key part of Zero's sustainability strategy since they are grid tied to utility power. This allows for charging off the electric utility grid and then discharging back to the same source with minimal energy losses.

Figure 27: Implementation of DC Tools for Manufacturing

Source: Zero Motorcycles

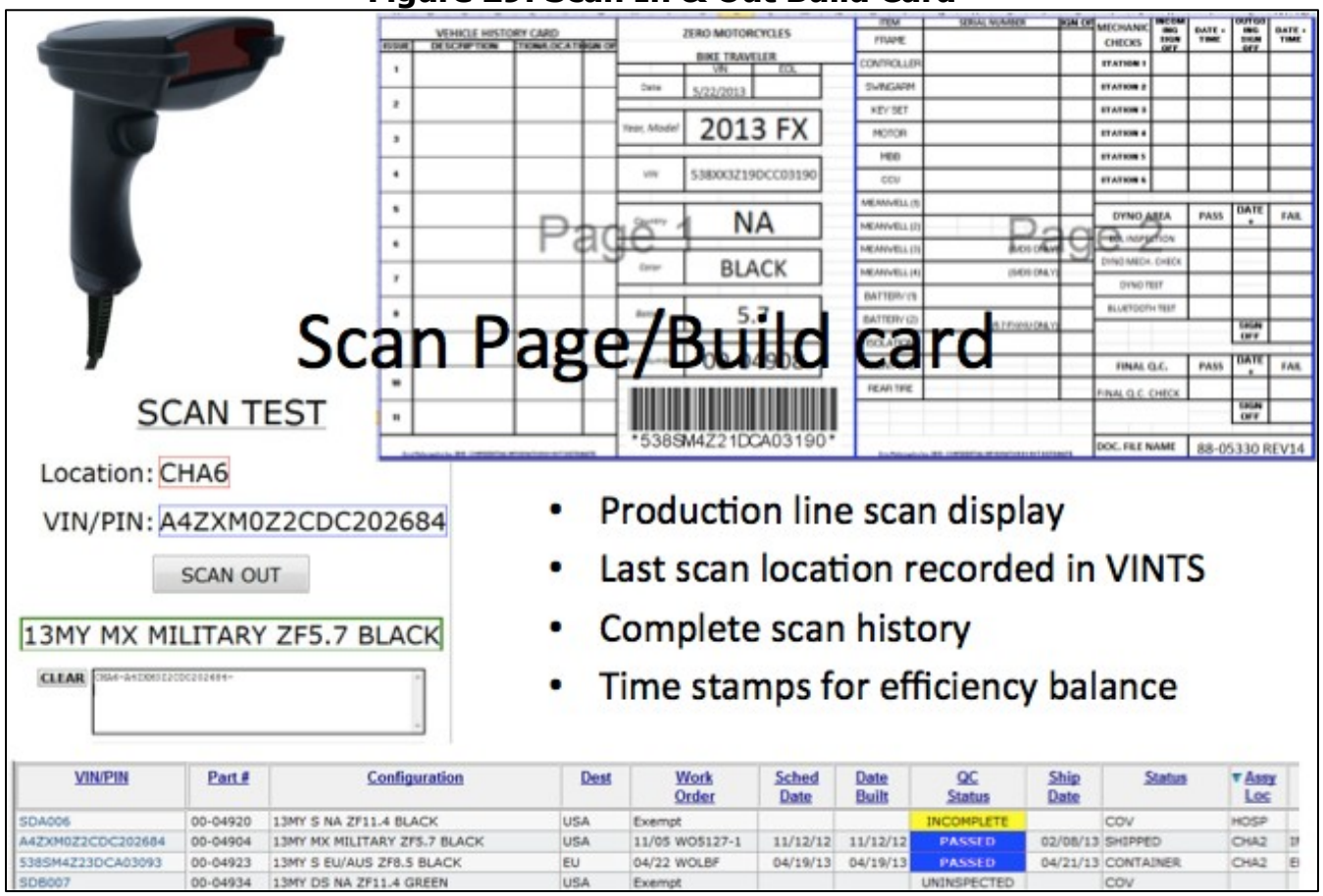
Figure 28: Two AeroVironment MT-30 DC Battery Cyclers

Source: Zero Motorcycles

Zero was also able to make significant gains with the implementation of radio data terminals for scanning in and out of each workstation and new software which was implemented for the project which integrates time tracking and production line management to optimize production capacity. The software required an initial investment of about $40,000 and has yielded dramatic improvements in our ability to optimize individual station performance.

As shown in Figure 23, each motorcycle passes through 8 stations. The stations each allow the operators to perform key tasks. At Station C1 VIN, install controller, main harness are installed, then at Station C2 the motor, swingarm, shock, triple clamps, and handlebar are added. Next at Station C3 forks, and grips are installed. Station C4 is used to install lighting and commission the electric motor/powertrain. Stations C5-C7 provide the final motorcycle build completion with the installation of wheels, brakes, bodywork and seat. Figure 29 shows a typical Scan In/Out Build Card used to track each motorcycle as it moves through production and is monitored in the production control system.

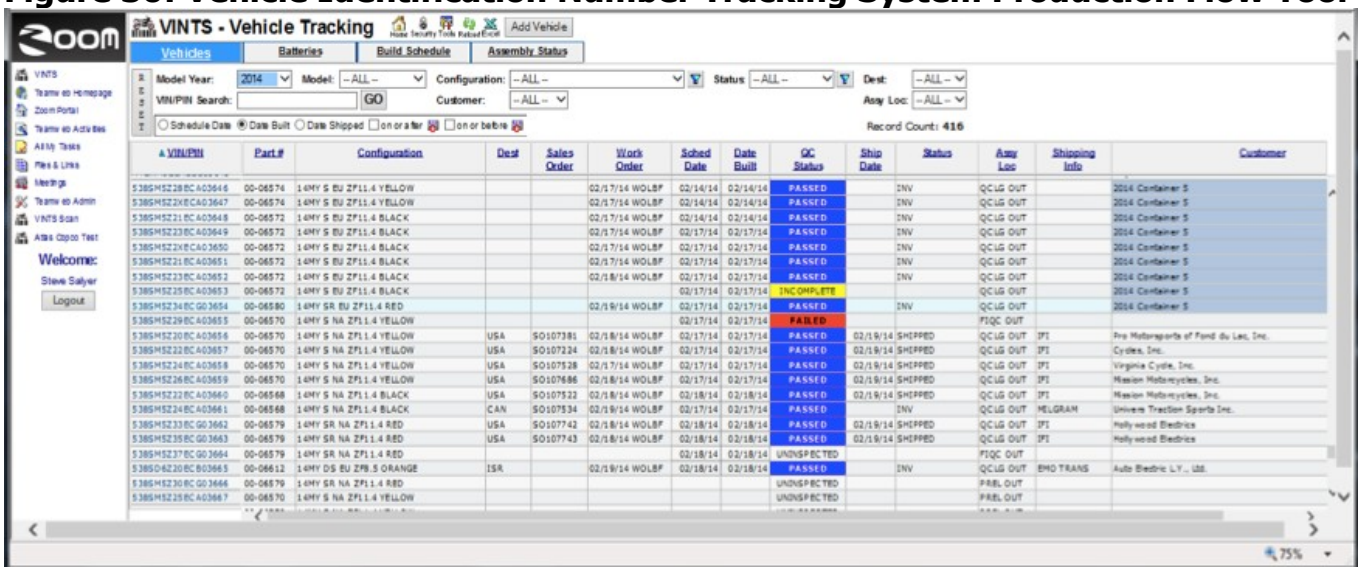
Figure 29: Scan In & Out Build Card



Source: Zero Motorcycles

The Vehicle Identification Number Tracking System software (Figure 30) which was originally implemented to track motorcycles and their components was ideally suited for modification into a complete production tracking system. As the motorcycles move through the line they are tracked and updated, providing both operator and supervisor feedback. The Zero production engineering staff can also use this data to rebalance the line if it turns out that any task is taking too long or if a station is underutilized.

Figure 30: Vehicle Identification Number Tracking System Production Flow Tool



Source: Zero Motorcycles

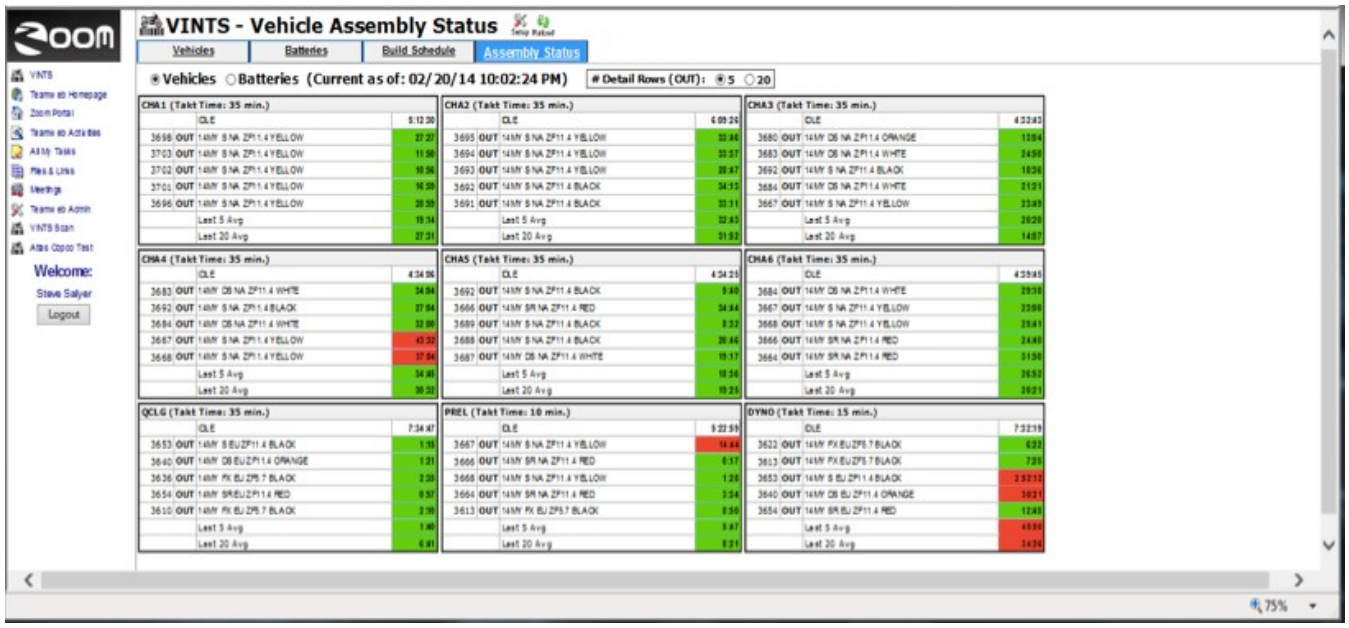
Full Manufacturing Line Performance

As previously discussed, at the beginning of the SEVMC project, Zero envisioned implementation of a fully automated production line to gain the greatest efficiency. As we completed the early tasks in this project it became clear that what was actually needed was a full process redesign and the implementation of a flexible production line which would be capable of building a wider variety of electric motorcycles, ranging from the Zero FX, to the Zero Police Fleet motorcycles which often need to be produced by the hundreds. The shift from automated manufacturing line to flexible manufacturing line was one of the key lessons learned from the project.

As part of this project, Zero has successfully moved from an almost completely manual production process at the beginning of this project to a highly streamlined manufacturing line with automated tools and production control via the Vehicle Identification Number Tracking System.

The Vehicle Identification Number Tracking System software implementation enabled the production engineering staff to move beyond stopwatches and timing charts to the point where they watch the line production at their computers on a real time basis. Figure 31 above shows the Takt time results of the production line stations for the last five motorcycles as well as the daily averages and running time. It can also highlight stations which have issues or slowdowns (as show in red). This allows for rapid intervention or line rebalancing to keep the production flowing at its optimal level.

Figure 31: Vehicle Identification Number Tracking System Vehicle Assembly Status Tool



Source: Zero Motorcycles

The SEVMC project was well suited to allow these kinds of performance improvements as each task built on the efficiency improvements of the previous one. During Task 3, durability and refinement motorcycles were assembled on the pilot line and then disassembled and rebuilt again. As Task 4 began, the same process allowed testing and building of 27 validation motorcycles (Figure 32), several of which were run through the production line multiple times. This created an opportunity for the operators to become highly proficient in their production and for the production engineering staff to optimize the flow and production process. As Vehicle Identification Number Tracking System came online during the latter part of Task 4, the line was able to be truly optimized with real time flow data.

Figure 32: 14MY Validation Inventory

14MY Validation bike build plan, updated 08/23/13

	S	SR	DS	SP	DSP	FXL	FX	MMX	Total	Notes:
Engineering	1EU8.5	1EU14.2, 1EU11.4	1EU8.5, 1EU14.2	1EU11.4	1EU14.2, 1NA14.2	1EU5.7	1EU5.7, 1UK5.7, 1NA5.7	1NA5.7	13	6 Val durability, 5 Homologation/Cert (Homologation bikes get transferred to Sales after Cert), 2 ABS development. MMX is base config.
Marketing	1NA14.2	1EU11.4	1EU11.4	0	1EU11.4	1NA5.7	1EU5.7	0	6	Photo/Video, EICMA, IMS
Sales	0	0	0	0	1NA14.2	0	0	1NA5.7	2	Marketing literature and fleet development
Manufacturing	0	1NA11.4	0	1NA8.5	0	0	1NA2.8	0	3	Manufacturing MP's
CS	0	1NA11.4	0	0	1NA14.2	0	1NA2.8	0	3	Technical publication creation
Total	2	5	3	2	5	2	6	2	27	

Colors:	S	SR	DS	SP	DSP	FXL	FX	MMX
Engineering	Black	2xRed	Wht,Ong	Black	2xBlack	Black	3xBlack	Black
Marketing	Yellow	Red	Orange		White	Black	Black	
Sales					White			Black
Manufacturing		Red		White			Black	
CS		Red			Black		Black	

Batteries:	S	SR	DS	SP	DSP	FXL	FX	MMX	
ZF11.4 on Bikes	1	5	2	1	5				14
ZF8.5 on Bikes	1	0	1	1	0				3
ZF2.8 on Bikes	1	1	1	0	4	4	10	4	25

ZF11.4 Spares	1	ZF8.5 Spares	0	ZF2.8 Spares	2		Engineering spares
Monoliths	18	Modules	27	Total cell-boxes	96		
				Total empty cellboxes	4		Use in 3-celbx packs, plus 1 spare

Source: Zero Motorcycles

Zero produced 27 Validation motorcycles during Task 4. The set of images in below in Figure 33 show four representative samples of the motorcycles produced for Task 4.

Figure 33: 14MY Validation Motorcycles

(Clockwise from upper left – Zero DS, Zero S, Zero FX, Zero SR)

Source: Zero Motorcycles

One of the key metrics for this project (and for the production line) was the achievement of a 50 percent improvement in production workflow (as measured by motorcycles produced per labor hour) via process and design updates. The measurement of this metric is usually made using Takt time which derives from the original Toyota Production System innovation.

"Takt time, derived from the German word **Taktzeit**, translated best as *meter*, sets the pace for industrial manufacturing lines so that production cycle times can be matched to customer demand rate. For example, in automobile manufacturing, cars are assembled on a line, at a certain cycle time, ideally being moved on to the next station within the takt time so as to neither over nor under produce. The cycle time to complete work on each station is often less than the takt time in order to ensure that the customer is never short of product. Although theoretically you want to match cycle time to takt time to avoid building inventories and over sizing equipment, the reality is that demand is dynamic and never precisely known and also process disruptions such as unplanned downtime can occur. Thus, in practice, it is generally understood that cycle time needs to be slightly less than takt time."[1]

Zero leveraged all of the engineering and manufacturing process improvements to go from a Takt time of 66 minutes per station down to just 37 minutes per station by the end of Task 4. This represents an improvement of 78 percent. This also translates into a motorcycle coming off the line every 37 minutes versus every 66 minutes. The overall manufacturing time went from 6:08 hours per motorcycle down to 4:10 hours, an improvement of 47 percent.

Zero clearly met and exceeded the goal of a 50 percent improvement in production workflow (as measured by motorcycles produced per labor hour) via process and design updates.

[1] Takt Time. *Wikipedia*. https://en.wikipedia.org/wiki/Takt_time

CHAPTER 6: Conclusion

Project Success - Better Manufacturing Right Here in California

Zero Motorcycles was able to successful scale manufacturing and engineering processes for the production of electric motorcycles in Scotts Valley, CA; achieving more than a 50 percent improvement in production workflow via process and design updates; as it leveraged capital expenditures to invest in an additional manufacturing capacity. With the above improvements, Zero accomplished its goal of quadrupling of overall electric motorcycle manufacturing capacity by the end of the project, with fully scalable manufacturing lines in place (Figure 34).

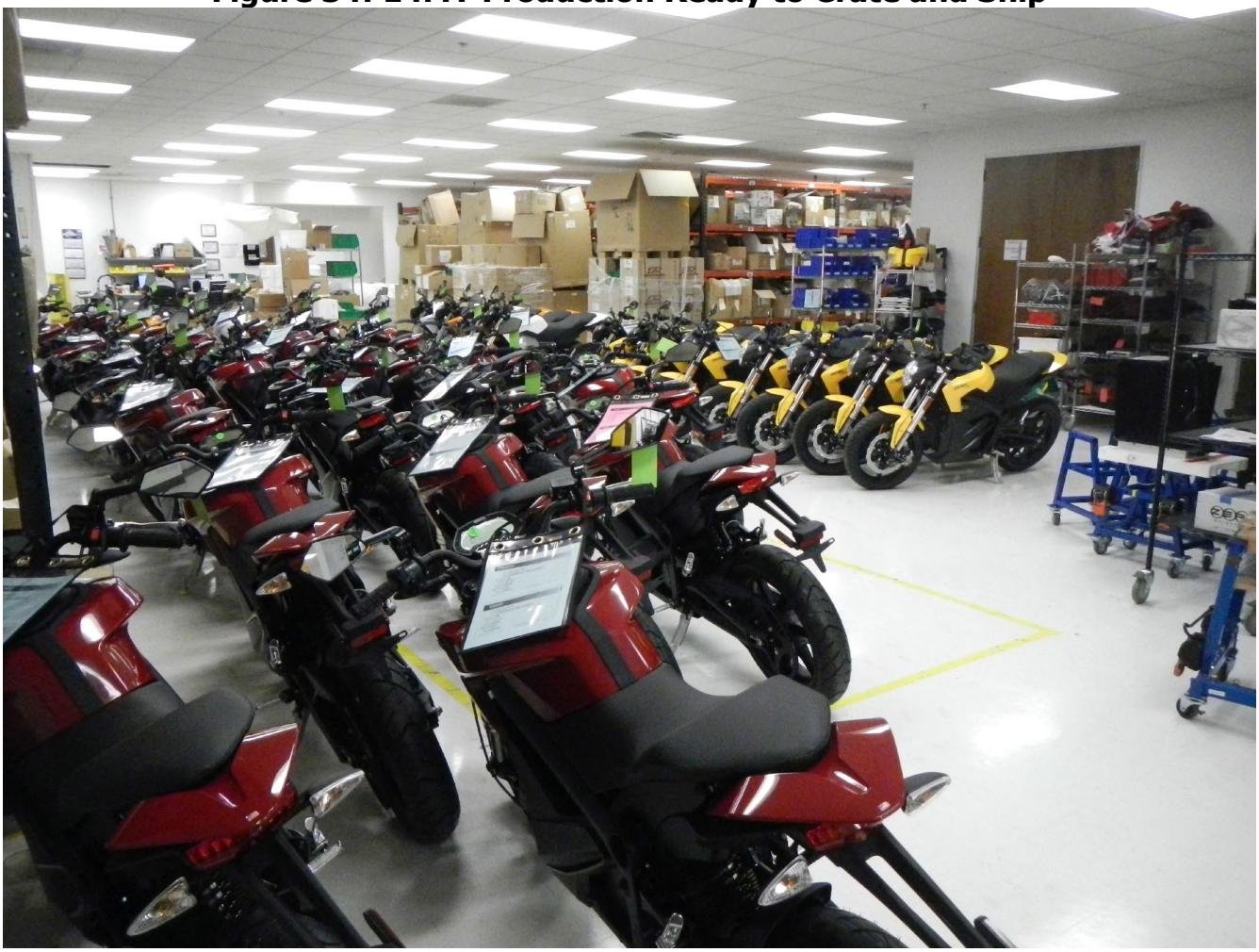
The project was a success in all areas, beginning with a redesign of the individual electric motorcycle product components and subassemblies to increase their manufacturing efficiency. Then Zero reviewed its manufacturing processes to scale the production of these its 14MY motorcycle designs. From this review, substantial improvements in manufacturing production workflow and efficiency via process optimization and automation were achieved. Zero also identified and procured capital equipment to help implement efficiency processes and procedures, reducing cost and directly expanding capacity.

Zero successfully met all of the SEVMC project objectives. At each step of the way Zero improved its engineering and manufacturing processes improving the scalability of its overall production. By the completion of the project, Zero leveraged all of the engineering and manufacturing process improvements to go from 66 minutes per station down to just 37 minutes per station. This represents an improvement of 78 percent. The overall manufacturing time went from 6:08 hours per motorcycle down to 4:10 hours, an improvement of 47 percent. Zero clearly met and exceeded the goal of a 50 percent improvement in production workflow (as measured by motorcycles produced per labor hour) via process and design updates.

Zero leveraged almost $2 million in CEC and match funding for capital equipment to go from a fundamentally manual production system to a modern, flexible, and significantly more automated manufacturing line with much higher degrees of process control. Not only will this gain Zero the quadrupling of production capacity it sought, but it will come with higher quality product output as well.

This project has provided a platform to dramatically increase the California based manufacturing capacity of the next generation of efficient, practical electric vehicles and in turn reduced its cost of production. Zero Motorcycle's project has been a unique opportunity to expand Greentech manufacturing in the State of California and on the Central Coast, keeping the competitive advantage of our skilled labor force, and helping to create twenty additional jobs during both the implementation and volume manufacturing stages of the project.

Figure 34: 14MY Production Ready to Crate and Ship



Source: Zero Motorcycles

Scientific and Technology Advancement

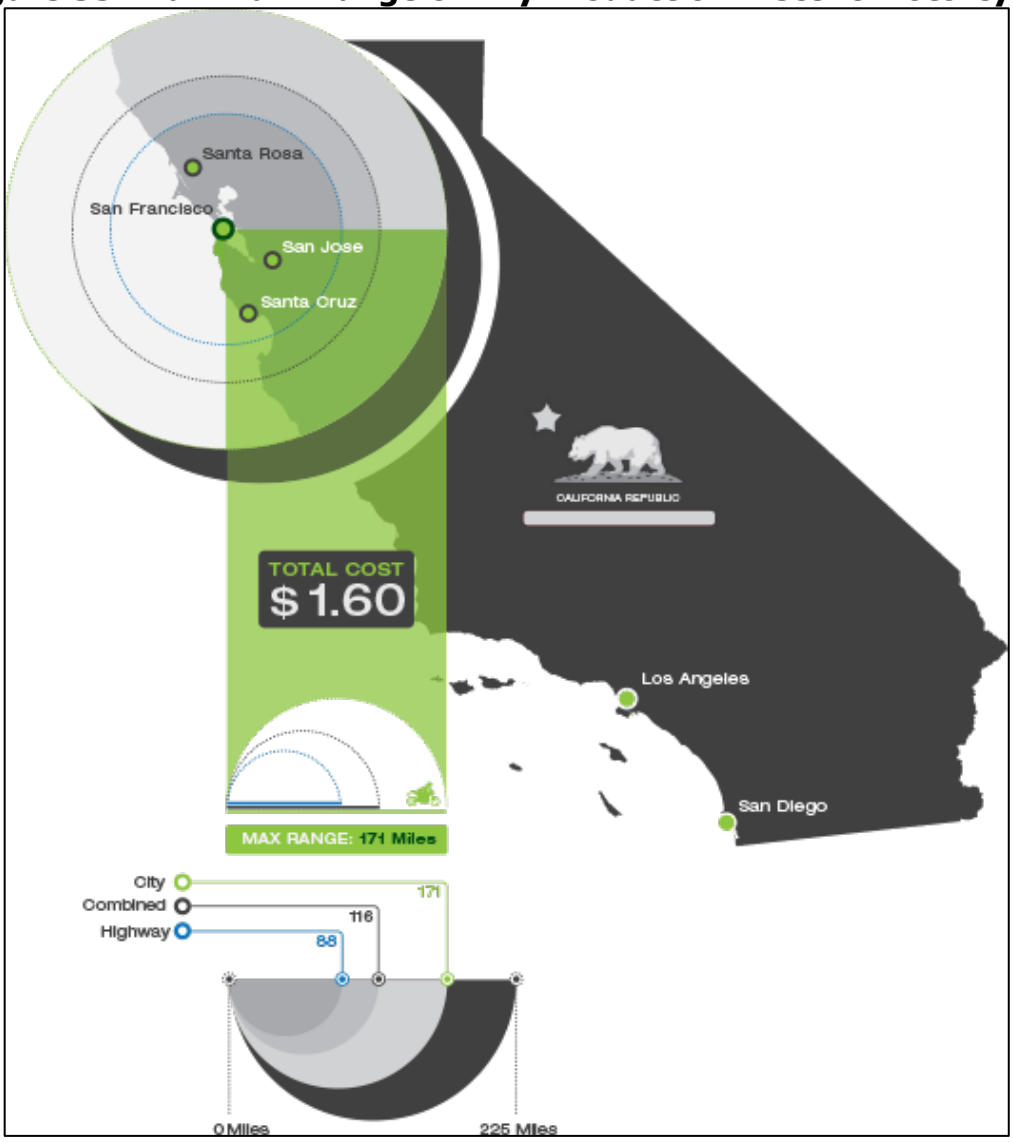
In order to meet the greenhouse gas (GHG) reduction goals of 20 percent by 2020 and 80 percent by 2050, California must replace petroleum with noncarbon based fuels. According to the California Air Resources Board (ARB), the only long-term fuel solution that will achieve the required reduction is electricity. Based on the "2050 Greenhouse Gas Emissions Analysis: Staff Modeling in Support of the Zero Emission Vehicle Regulation"[2], ARB estimates that 100 percent of all vehicles sold by 2040 must be zero emissions vehicles using electric drivetrains.

The ARB report states, "Because it takes decades for a new propulsion system to capture a large fraction of the passenger vehicle market due to vehicle fleet turnover rates, it is important to accelerate the introduction of low carbon vehicle alternatives to ensure markets enter into precommercial volumes (10,000s) between 2015 and 2020." Zero's SEVMC project does exactly this– we reach high volume manufacturing within 12 months of project completion. The vehicles built on this manufacturing line will also be affordable and accessible, further expanding market penetration.

[2] Zero Emissions Vehicle Program https://ww2.arb.ca.gov/our-work/programs/zero-emission-vehicle-program

Leveraging the results of this project, along with significant anticipated advances in battery technology, we expect continuous improvements in our electric powertrain technology that will drive both increased capability and further cost reductions. We expect that within the next 10 years, this advanced electric vehicle technology will reach parity with internal combustion engines, and then surpass it on many metrics. Already today we are seeing electric vehicles that meet or exceed consumers' expectations, and as we push the technology curve, we will broaden their market acceptance. Today, hybrids represent about 5 percent of all vehicle sales. In the near future, electric drive technology will penetrate the marketplace more quickly and then transform broad sectors of the transportation industry. California census data reveals that many citizens have a commute that is within range for riding a motorcycle, with over 16.3M commuters in California alone (Figure 35).

Figure 35: Maximum Range of Any Production Electric Motorcycle



Source: Zero Motorcycles

Benefits to the State of California

California relies excessively on a single fuel to meet 96 percent of its transportation needs. Clearly, the need for fuel diversity is paramount, and this program has opened up new

areas of the transportation and recreational motor market to alternative fuels, specifically ubiquitous electricity.

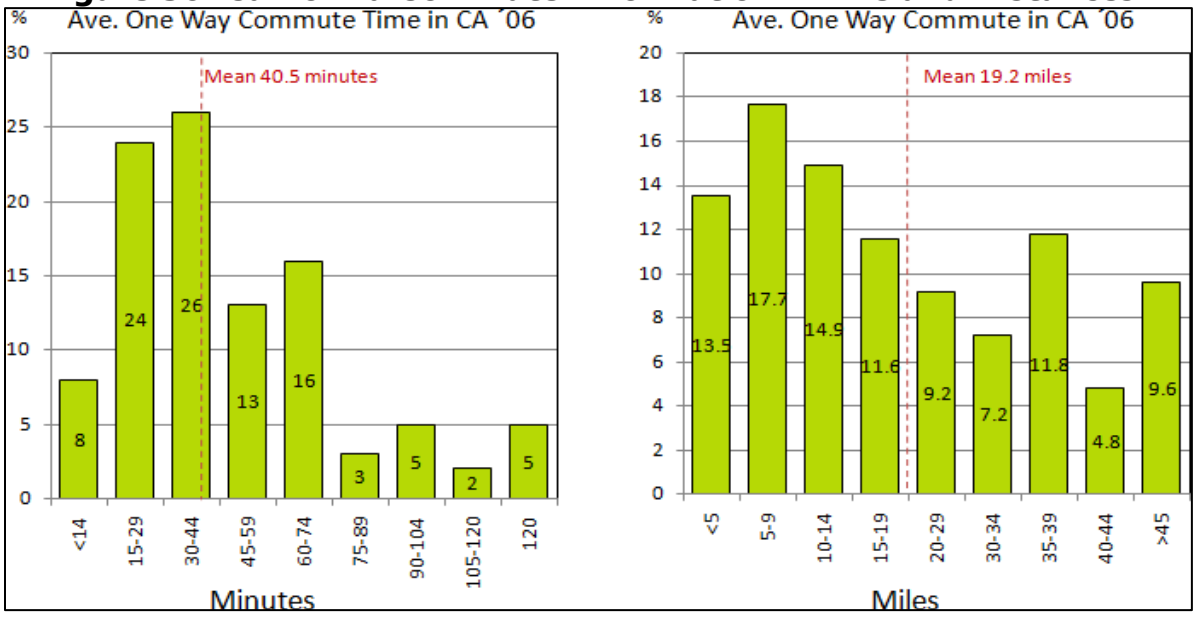
Electric Motorcycles Reduce Emissions and Petroleum Consumption

Zero Motorcycles believes that electrification of transportation represents the single greatest opportunity to positively affect the dynamics of climate change. By shifting as many vehicles as possible to electric drive and transferring the vehicle miles traveled to electricity, we can achieve the critical GHG reductions targeted by the state of California. This project approached the challenge in several ways.

The primary goal of the project was to significantly increase the manufacturing capacity of a California electric vehicle manufacturer, starting with the most affordable – electric motorcycles.

It is clear that with the shifting transportation landscape, many consumers are considering motorcycles as a commuting alternative. According to American Community Survey data released by the US Census Bureau in March 2005, "Americans spend in excess of 100 hours commuting to work each year. For the nation as one, the average daily commute to work lasted about 24.3 minutes in 2003 (Figure 36). A motorcycle or a scooter does not offer a lot of passenger room or storage space, but most get far better mileage than even a hybrid car and at a far cheaper price. Moreover, two wheelers have the added advantage of maneuverability to beat the rush hour traffic. With fuel prices skyrocketing, motorcycles and scooters can be a practical fuel economy transportation option for the typical half hour drive to work."[3]

Figure 36: California Commute Information - Time and Distances[4]



Source: Southern California Association of Governments

[3] March 2005 American Community Survey https://www2.census.gov/programs-surveys/cps/techdocs/cpsmar05.pdf

[4] "2006 State of the Commute", Southern California Association of Governments, http://www.scag.ca.gov/Documents/2006_StateoftheCommute_Report.pdf

A Consumer Reports Auto Pulse survey found that 26 percent of people would consider switching to either a motorcycle or motor scooter[5]. As discussed in the Market Viability section, California is the largest market in the United States for motorcycles. More benefits from the advanced electric powertrain will be realized in California than anywhere else in the US.

By targeting electric motorcycles initially, we can take advantage of consumer interest and desire for a fun means of transportation at a price point significantly lower than other electric vehicles. We also capture a market segment that has been traditionally more polluting and has generated more GHG due to lower standards for the engines in this class. The advanced electric powertrains we build will have zero tailpipe emissions and represent at least an 89 percent reduction in carbon intensity as compared to similar gasoline engines.

According to ARB, motorcycles account for 3.6 percent of registered vehicles in the state and make up just 0.8 percent of vehicle miles traveled, yet account for ten percent of passenger vehicles smog forming emissions. Although fuel-efficient bikes emit significantly less carbon dioxide per mile, the ARB says they are, on average, 14 times more polluting per mile when it comes to emissions of oxides of nitrogen and hydrocarbons bb smog forming pollutants that have been shown to trigger asthma attacks and worsen respiratory and cardiac illnesses. Electric motorcycles are an ideal solution for this problem since they are inherently zero emission vehicles at the local level.

The ARB estimates that 5.2 tons of pollutants would be prevented from entering the atmosphere daily if motorcycle smog checks become law. Broad market penetration of electric motorcycles would dramatically reduce pollutants since they are 14 times cleaner than their gasoline counterparts.

Manufacturing Electric Motorcycles for Increased Employment

As Zero completes the SEVMC project, we believe we can scale the overall electric motorcycle manufacturing to achieve significant volume, changing the manufacturing dynamics, and expanding California employment.

This project directly created fifteen additional jobs at Zero Motorcycles. In addition, during the grant timeframe, Zero has grown from 80 employees to 110 employees, with much of the growth attributable to product improvements directly or indirectly related to the grant project.

Zero will continue to create more California jobs by focusing its capital and human resources on full vehicle electric motorcycle production in California. This effort will lead to the creation of new cleantech jobs. Leveraging the work of the SEVMC project, Zero will be able to produce more electric motorcycles, exceeding consumer expectations as we replace internal combustion vehicles in the California fleet, simultaneously achieving broad gasoline and GHG reductions.

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[5] Consumer Reports, Downsizing to Two Wheels, 7/1/2008, https://www.consumerreports.org/cro/news/2008/07/downsizing-to-two-wheels-motorcycle-interest-revs-up/index.htm

CHAPTER 7: Next Steps

Zero is very encouraged by the results of this project and is pursuing several future objectives. First, Zero will continue to expand manufacturing capacity to meet customer demand and leverage the key personnel who have joined the company as part of the program. Zero now has deeper expertise in production engineering, manufacturing, development, and programming, battery technologies, and real-time systems integration. Our engineers have become better versed in "design for manufacturing techniques". As we grow in California, Zero will use its unique position in the market to attract the best talent and expand both R&D and manufacturing operations.

Zero is already deploying its own new capital to expand operations beyond the support of the SEVMC project. An excellent example is our purchase of a second AeroVironment MT-30 to enhance the throughput of our battery manufacturing line. The MTb30 funded by the CEC proved its utility and justified the purchase of additional capital equipment.

Zero is focused on fully evaluating its entire supply chain at each new model year introduction, with the intent to onshore as many components as possible, especially with manufacturing partners in California. We continue to look for opportunities to enhance our own manufacturing capability wherever possible. Zero has shown significant sales and revenue growth over the past two years during the timeline of this grant program and has determined that we will be able to dramatically expand and build capacity for full motorcycle manufacturing here in California (Figure 37).

The market for electric vehicles is growing rapidly and the SEVMC project provides a major opportunity for a small company like Zero Motorcycles, Inc. to have a major impact on the overall marketplace.

Figure 37: Zero Proud to be Crafted in California

Source: Zero Motorcycles

GLOSSARY

CALIFORNIA AIR RESOURCES BOARD (ARB)—The "clean air agency" in the government of California whose main goals include attaining and maintaining healthy air quality, protecting the public from exposure to toxic air contaminants, and providing innovative approaches for complying with air pollution rules and regulations.

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The CEC's five major areas of responsibilities are:

1. Forecasting future statewide energy needs.
2. Licensing power plants sufficient to meet those needs.
3. Promoting energy conservation and efficiency measures.
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels.
5. Planning for and directing state response to energy emergencies.

Funding for the CEC's activities comes from the Energy Resources Program Account, Federal Petroleum Violation Escrow Account, and other sources.

CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA - pronounced See' quah)—Enacted in 1970 and amended through 1983, established state policy to maintain a high-quality environment in California and set up regulations to inhibit degradation of the environment.

DIRECT CURRENT (DC)—A charge of electricity that flows in one direction and is the type of power that comes from a battery.

GREENHOUSE GAS (GHG)—Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (NOx), halogenated fluorocarbons (HCFCs), ozone (O3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

MODEL YEAR (MY)—The term model year means a manufacturer's annual production period (as determined by the Federal Trade Commission) for motor vehicles or a class of motor vehicles. If a manufacturer has no annual production period, the term "model year" means the “calendar year.”